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ORIGINAL ARTICLES

THE PROBLEM OF INTER-PROVINCIAL PLANT QUARANTINES IN INDIA *

BY

G. WATTS PADWICK

Imperial Mycologist, Imperial Agricultural Research Institute, New Delhi

AND

B. N. UPPAL

Plant Pathologist to the Bombay Government, Agricultural College, Poona

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Crop categories in India

INDIA is frequently referred to as a sub-continent, a description it acquires by virtue of its separation from the rest of Asia on its northern boundary by the Himalayas. There are land-passes of fairly low altitudes at the eastern and western extremities of the range, but in general the mountains prevent the free passage of goods almost as effectively as the sea. The rest of India is divided into two main areas, the northern plains, and the central and southern plateau. In the southern plateau there are only a few high elevations. The Western Ghats rise to an elevation of about 3,000 ft. with peaks of nearly 9,000 ft. The Eastern Ghats have an average elevation of only about 1,500 ft., with much lower peaks.

The plains of northern India have a climate divisible into four distinct seasons ; the cold weather, from November or December (according to locality) to March or April ; a period of extreme heat following ; the monsoon period of lesser heat and higher humidity ; and the post-monsoon period of September and October, with a second rise in temperature accompanied by a gradual fall in humidity. Southern India's climate, at least in the lower altitudes, is a mild modification of that of the plains, the hot weather starting much sooner but never reaching the same heights, and the cold weather being modified. The Himalayas and the southern hill ranges contain considerable areas of temperate climate, isolated from one another by areas of lower elevation with higher summer temperatures. Thus, for instance, the Nilgiris in Madras, Mahabaleshwar in Bombay, Kodaikonal and Nandi Hills (Madras), the Eastern Ghats in Madras and Orissa, the Vindhyas in Central India and the Central Provinces, are all separated by wide expanses of low-lying lands. In these hilly areas, temperate crops, notably fruits and vegetables, are grown. Again, in the Himalayas there are substantial areas devoted to similar crops in Quetta, Baluchistan, North-West Frontier Province, Kashmir, Kulu in the

*This paper was originally submitted for the Fourth Imperial Mycological Conference, to have been held in London in September 1939. The Conference was cancelled. The anticipated paper had, however, aroused interest outside India, and was submitted for publication here at the suggestion of the Director of the Imperial Mycological Institute, Kew.

Punjab, Ramgarh and Chaubattia in the United Provinces, and Sikkim, all isolated from one another by long distances although connected by a common elevation level.

In addition to separation by mountain areas, there is another form of barrier in India, namely desert area. Actually there is only one such important area, the Rajputana desert, an area of extremely high temperatures and low rainfall in which the crops are mainly those which can grow on the small amount of residual moisture resulting from the meagre monsoon showers.

In brief, then, India consists of one large plain growing tropical or sub-tropical crops, cut up in many parts of the south by isolated hill ranges, and bounded on the north by the huge range of the Himalayas. It is like an ocean dotted with islands, the ' ocean ' being the area of low elevation having an almost continuous connection throughout, the ' islands ' being the high elevations, separated completely and frequently isolated from one another in this manner by great distances.

The staple foodstuffs of India grow on the plains, the hills growing only special crops such as temperate fruits and vegetables, with a mere smattering of the staple crops such as wheat, *jowar*, maize, pulses etc. The staple foodstuffs (the pulses and cereals) and also the major fruits (oranges, mangoes bananas etc.) are grown throughout the lower elevations of India. Naturally there are areas particularly noted for certain crops. Thus, for example, the drier belt of the northern plains (west United Provinces and the Punjab) relies largely on gram (*Cicer arietinum* L.) as a pulse, whereas the wetter part of the plains (east United Provinces and Bihar) grows mainly pigeon-pea (*Cajanus cajan*). Yet both gram and pigeon-pea can be found in considerable quantities in Bihar and the Punjab—and indeed in any province of India. Rice, the staple diet of large parts of Bengal, Madras, and Kashmir, is a crop eminently suited for wet climates, yet it will be found in small quantities even in very dry areas provided a small spot of low-lying land can be found near a river-bed. Similarly the best bananas, and by far the largest quantities, are grown in Southern India (Madras, Bombay, Mysore etc.) but there are no low-land parts of India without their bananas, usually their own local variety.

With commercial crops, there is some difference. Jute, for instance, is restricted to a small area in Bengal, coffee to Travancore and Mysore, and tea to a few districts in Southern India and the north-eastern Himalayas. On the other hand sugarcane, which has developed commercially only in Bihar and the United Provinces to a substantial extent, is grown all over India for local consumption.

The crops of India may conveniently be divided into six categories, as follows :—

(1) The staple foodstuffs (grains and pulses) grown throughout the northern plains and southern lowlands, and to a very small extent in the hills.

(2) The sub-tropical and tropical fruits, with a similar distribution.

(3) Commercial crops of restricted distribution (e.g. jute, tea and coffee) limited by climatic factors.

(4) Commercial crops of wide distribution (e.g. cotton, tobacco and sugarcane).

(5) Temperate crops of restricted distribution (e.g. temperate fruits such as apples, pears and plums) grown in the hills.

(6) Temperate crops of wide distribution (e.g. common European vegetables) grown during the warm weather in the hills and during the cold weather on the plains.

Distribution of diseases

No systematic survey of diseases has ever been conducted in India, for the simple reason that the number of plant pathologists has never been adequate. We are, however, able to get a certain amount of information in some cases, and since the question of quarantine cannot even be intelligently considered without some knowledge of disease distribution we have drawn heavily on published literature to gain some insight of the subject. Numerous publications have been referred to, but particular mention may be made of '*Fungi of India*' by Butler and Bisby, the '*Fungi of India—Supplement I*' by Mundkur, and '*Fungi of Bombay*' by Uppal, Patel and Kamat. By reference to these and numerous other publications it has been possible to list in Table I, we hope without many omissions, the recorded occurrence of the important diseases of a number of selected crops. In preparing this table we have selected a few important crops from all six 'categories' described above. We have listed all the diseases occurring on these crops in India which have either shown themselves capable of causing severe damage in India itself or else are known to cause severe injury in some other country. The diseases thus analysed total sixty-eight.

Table I

Recorded distribution of fungous diseases of some important Indian crops, which cause severe damage or are considered potentially dangerous judging by their behaviour elsewhere

Crop	Category	Disease	Cause	Distribution
Wheat	1	Stem rust	*Puccinia graminis* Pers.	General
		Brown rust	*Puccinia triticina* Erikss.	General
		Yellow rust	*Puccinia glumarum* (Schm.) Erikss. and Henn.	Northern India and Nilgiris
		Loose smut	*Ustilago tritici* (Pers.) Jensen.	General
		Leaf spot	*Septoria tritici* Desm.	Punjab
		Root-rot	*Helminthosporium sativum* P. K. and B.	Pusa (Bihar)
		Flag smut	*Urocystis tritici* Koern.	Punjab
		Indian bunt	*Neovossia indica* (Mitra) Mundkur	Punjab and N.-W. F. P.
		Bunt	*Tilletia caries* (DC.) Tul. *Tilletia foetans* (Berk. and Curt.) Tul.	Himalayas
Barley	1	Covered smut	*Ustilago hordei* (Pers.) Kellerm. and Swingle	General
		Stem rust	*Puccinia graminis* Pers.	General
		Yellow rust	*Puccinia glumarum* (Schm.) Erikss. and Henn.	Northern India and Nilgiris

TABLE I—*contd.*

Crop	Category	Disease	Cause	Distribution
Barley	1	Stripe	*Helminthosporium gramineum* Rabenh.	Pusa (Bihar) and Punjab
		Root-rot	*Helminthosporium sativum* P. K. and B.	Pusa (Bihar) and Punjab
		Net blotch	*Helminthosporium teres* Sacc.	Pusa (Bihar) and Punjab
Oats	1	Smut	*Ustilago avenae* (Pers.) Jensen	General
		Leaf spot	*Helminthosporium avenae* Eid.	General
Jowar (Sorghum)	1	Grain smut	*Sphacelotheca sorghi* (Link) Clinton	General
		Long smut	*Tolyposporium Ehrenbergii* (Kühn) Pat.	General
		Downy mildew	*Sclerospora sorghi* (Kulk.) West. and Uppal	General
Pigeon-pea	1	Wilt	*Fusarium vasinfectum* Atk. (?)	General
		Root-rot	*Macrophomina phaseoli* (Maubl.) Ashby	General
Gram	1	Blight	*Mycosphaerella rabiei* Kovachevsky	Punjab and N.-W. F. P.
		Wilt	*Fusarium* sp.	General
Citrus	2	Canker	*Pseudomonas citri* Hasse	General
		Gumosis	*Phytophthora palmivora* Butler	Throughout the Bombay-Deccan.
		Wither-tip	*Colletotrichum gloeosporioides* Penz.	General
Mango	2	Sooty mould	*Dimerosporium mangiferum* Cke. and Br.	Mysore ; Punjab and U. P.
		Twig blight	? *Dotheorella mangiferae* Syd.	Lucknow, U. P.
		Anthracnose	*Glomerella cingulata* (Stonem.) Spauld. and v. Schrenk	Madras and Punjab (common on other hosts elsewhere)
Jute	3	Root-rot	*Macrophomina phaseoli* (Maubl.) Ashby	Bengal (and throughout India on other hosts)
Rubber (*Hevea*)	3	Leaf-fall	*Phytophthora palmivora* Butler	Throughout the *Hevea*-growing districts of Burma and South India
			Phytophthora meadii McRae	There is some confusion as to the identity of the two organisms, Dastur having suggested that they are identical. In any case *Phytophthora palmivora* at least is widespread on several hosts
		Pink disease	*Corticium salmonicolor* B. and Br.	Widespread in the *Hevea*-growing districts of Assam, Burma and South India
		Mildew	*Oidium hevae* Steinman	Travancore
		Leaf-fall	*Gloeosporium alborubrum* Petch.	Travancore
		Die-back	*Botryodiplodia theobromae* Pat.	Burma. The fungus is of general distribution on other hosts
		Root-rot	*Fomes lamoensis* (Murr.) Sacc. and Trott.	*F. lamoensis* is of general distribution ; *G. pseudoferreum* has been reported from Burma
			Ganoderma pseudoferreum (Wakef.) von Overeem and Steinman (*Fomes pseudoferreus* Wakef.)	

TABLE I—*concld.*

Crop	Category	Disease	Cause	Distribution
Sugarcane	4	Red-rot	*Colletotrichum falcatum* (Went.)	General
		Wilt	*Cephalosporium sacchari* Butler	General
		Smut	*Ustilago scitaminea* Syd.	General
		Top-rot (Pokkah-beong)	*Fusarium moniliforme* Sheld.	General
		Mosaic	Virus	General
Cotton	4	Wilt	*Fusarium vasinfectum* Atk.	General
		Root-rot	*Macrophomina phaseoli* (Maubl.) Ashby	General
		Anthracnose	*Glomerella Gossypii* (Southw.) Edg.	Pusa (Bihar)
		Blight	*Colletotrichum indicum* Dastur	Central Provinces
		Angular leaf-spot	*Pseudomonas malvacearum*.	Punjab
Tobacco	4	Leaf-spot	*Cercospora nicotianae* Ell. and Ev.	General
		Wilt	*Bacterium solanacearum* E. F. Sm.	Bengal (and in various parts of India on potatoes)
		Mildew	*Erysiphe cichoracearum* DC.	General
	4	Mosaic	Virus	General
		Leaf-curl	Virus	Northern India and Bombay
Coconut	4	Bud-rot	*Phytophthora palmivora* Butler	Throughout the coconut districts of Bengal, Madras and Southern India. The disease is also common on *Borassus flabellifer* almost wherever grown
		Root-rot	?	Widespread in the Southern Peninsula
		Bleeding disease	*Thielaviopsis paradoxa* (de Seynes) v. Hohnel	Throughout southern and eastern India
Peach	5	Powdery mildew	*Sphaerotheca pannosa* (Wollr.) Lev.	Kashmir
		Leaf-curl	*Taphrina deformans* (Berk.) Tul	Mountainous tracts of Assam, Bihar, U. P., Kashmir, Punjab and N.-W. F. P.
		Brown-rot	*Scelerotinia cinerea* (Bon.) Schroet.	Kashmir ?
Apples	5	Root-rot	? *Rosellinia* sp.	United Provinces
		Die-back	*Botryosphaeria ribis* G. and D.	United Provinces
		Branch blister	*Coniothecium chomatosporum* Cda.	Kumaon hills, U. P.
		Powdery mildew	*Podosphaera leucotricha* (Ell. and Ev.) Salmon	Punjab, Kashmir and United Provinces
		Scab	*Venturia inaequalis* (Cooke) Wint.	Kashmir and Punjab
Potatoes	6	Early blight	*Alternaria solani* (Ell. and Mont.) Jones and Grout	General
		Scab	*Actinomyces scabies* (Thaxt.) Gussow	Khasi hills and Bombay
		Late blight	*Phytophthora infestans* de By.	Himalayas, Khasi hills, Assam, Bengal plains
		Dry-rot	*Fusarium* spp.	General
		Bacterial wilt	*Bacterium solanacearum* E. F. Sm.	Bombay, Mysore, United Provinces, Nilgiris

The following conclusions can be drawn from the table (Table I) at a glance.

(1) Of the sixty-eight diseases considered, twenty-seven are of general distribution throughout India, while in another six cases the fungi concerned have a wide distribution on other hosts. Of the remaining thirty-one diseases, fourteen are common in most parts of the country where the crops are grown, but have not been listed as being of 'general ' distribution because the crop itself is rather limited to special areas.

(2) There remain only twenty-one diseases of which the records indicate possibly a narrower distribution.

(3) The proportions of cases in which possibly a narrow distribution is indicated, as divided amongst the various crop categories, are indicated in Table II.

TABLE II

Proportions of diseases of wide and narrow distributions in India

Category	Description	Diseases of fairly wide distribution	Diseases of possibly narrower distribution
1	Staple foodstuffs (grains and pulses)	16	8
2	Sub-tropical and tropical fruits	5	1
3	Commercial crops of restricted distribution	5	2
4	Commercial crops of wide distribution	15	3
5	Temperate crops of restricted distribution	2	6
6	Temperate crops of wide distribution	4	1

In reaching the above conclusions, however, one point must be made clear. If the figures err at all, they err in the direction of multiplying unduly the ' diseases of possibly narrower distribution '. Three of these diseases (root-rot of barley, scab of potatoes, root-rot of apples) are soil-borne and may readily have escaped identification. Some are no doubt restricted by climatic conditions to certain districts. Yet others may have been observed in other districts but not reported, or may have escaped observation.

FEASIBILITY AND LIMITATIONS OF QUARANTINE BETWEEN NEIGHBOURING PROVINCES

It has been pointed out that geographically India consists of one large plain with a number of isolated hill or mountain tracts. The provincial boundaries bear very little relationship to the topography, and the hill tracts may be divided between a number of provinces. The natural barriers in the form of

mountains or deserts or climatic conditions are few. A large number of severel diseases are widespread ; a few may be of more limited distribution. Several questions now arise. Can we expect to control the spread of diseases by inter-provincial regulation of traffic in plants and plant products ; if so, should legislation be general or restricted to certain diseases ; and finally is it likely to pay, the anticipated savings being likely to exceed the cost of administration ?

There is at present a considerable inter-provincial trade in propagative material and material such as grains and pulses capable of being used for propagative purposes. The propagative materials include seeds, tubers, cuttings, seedlings, bulbs etc. The food-stuffs liable to transport diseases are mainly seeds, fruits and tubers. There is no guarantee that goods transported for consumption will not be used for propagation.

There are large numbers of points of entry between one province and another, and transport may be by road, rail or water.

There are, according to McCubbin [1936] five recognized types of quarantine action :—

Embargo

Detention

Disinfection

Inspection

Unrestricted entry

Embargo could certainly only be applied in very rare cases. It probably could not be used for crops of categories 1 and 2 (basic foodstuffs and fruits of the plains) in which there is extensive inter-provincial trade. The indications are that in crops of categories 3 and 4 (commercial crops) the potentially dangerous diseases are widely distributed and quarantine measures are not called for.

Detention, which means holding in quarantine during a fixed period of observation, needs a far greater expert staff than embargo. It might be adopted in the case of a few specific crops of categories 3 (commercial crops of restricted distribution) and 5 (temperate crops of restricted distribution), provided a specific case was made out.

The value of disinfection has been analysed by McCubbin and has been shown to be an important procedure only in the case of seeds. At the present time, however, we have no means of knowing, for the vast bulk of seeds transported (cereals and pulses) whether they are to be used for seed or consumption. Many of the best disinfectants are poisonous and there is little doubt that disinfected seed crossing a provincial frontier would lead to numerous cases of litigation and finally to a serious hampering of trade, to say nothing of the immense staff required for the purpose of disinfecting.

Inspection has been shown by McCubbin to have in itself very low rank for purposes of exclusion ; at the same time it requires a very large expert staff. It is considered by McCubbin to be a distinct quarantine function only when it alone is depended on as a means of protection. There are certain cases of vegetatively propagated plants, such as fruit trees and grafts, in which a considerable trade is done. Embargo is out of the question and disinfection methods cannot be used unless the exact details of the disinfection required

are known. If we are to have protection it must be through inspection or detention, and since detention may in some cases result in severe damage to the plants, inspection may prove most useful.

Unrestricted entry is considered by McCubbin to be safe for a large proportion of seeds. This is particularly fortunate, for the inter-provincial commerce in seeds, used either for propagation or for food, must be very great and there is little hope of adopting, at the present time at any rate, any method of treating this type of product, or even of adequately inspecting it.

To summarize, it seems that for the bulk of plant products in India, i.e. the foodstuffs (grains, pulses and fruits) grown on the plains, we are not at present justified in establishing inter-provincial quarantines, for the following reasons :–

(1) Embargoes would interfere with trade, detention is useful only for growing plants, and disinfection is dangerous.

(2) Adequate inspection of plant products generally would involve staffs completely beyond the power of the provinces to provide.

(3) The plains crops are on the whole widely distributed. Many of their diseases are similarly distributed, but in the absence of survey data we cannot say if this is true for all. It is difficult to name more than one or two cases where inter-provincial quarantine of this type could be expected to pay for itself.

(4) In these crops the largest commerce is in seeds, which according to McCubbin are the most safe category of plant products for unrestricted entry ; and fruit, which possibly does not serve largely as a distributor of disease.

(5) The plains crops are widely distributed, with few natural boundaries to prevent spread of diseases.

It is possible, however, that even amongst these crops there are specific cases for quarantine in propagating materials other than seed. In bananas the dangerous virus disease ' bunchy top ' has recently been suspected in two places in India. There is every reason why measures should be adopted to prevent suckers being sent from these places to healthy districts. Other similar cases may exist amongst virus diseases of vegetatively propagated plants.

The commercial crops of wide distribution such as sugarcane and tobacco have a very high proportion of their diseases distributed over wide areas, indicating that here little would be gained by quarantine measures. Those of narrower distribution have not been sufficiently thoroughly analysed to reach a very reliable decision, but even here the indications are of fairly wide distribution except in the case of two newly reported rubber diseases. Some restrictions designed to prevent distribution of rubber mildew (*Oidium hevae* Steinman) seem called for and should not be impossible with a crop grown by large planters.

As regards temperate crops, very considerable sums are at present being spent in research on cultivation of fruit in the hills. Many of the zones are well isolated from one another by long stretches of unfavourable climate. It seems as if there might be cases here for adopting the practice of examination and detention when plant parts for propagation are sent from one area to another. There would, however, be certain inter-provincial boundaries where the rules might be relaxed, as these boundaries do not as a rule coincide with topographical areas.

Basis for legislative action

The National Plant Board of America [1932] has indicated four fundamental prerequisites for the establishment of a quarantine, which do not suffer from repetition. They are as follows :—

(1) The pest concerned must be of such nature as to offer actual or suspected threat to substantial interests ;

(2) the proposed quarantine must represent a necessary or desirable measure for which no other substitute, involving less interference with normal activities, is available ;

(3) the objective of the quarantine, either for preventing introduction or for limiting spread, must be reasonable of expectation ;

(4) the economic gains expected must outweigh the cost of administration and the interference with normal activities.

The first prerequisite has a striking significance which may easily be overlooked. It eliminates at once the idea of basing legislation on a general footing. Experience has shown that the proper basis is the individual pest or disease. The obvious sequence is that we must know the distribution of our pest, or pathogen, its life-history, its potentiality for damage and the definite possibility of gains resulting from quarantine action. We now have a fair knowledge of many life-histories, and have a fair idea of potentialities for damage. We lack in many cases the all-important knowledge of distribution. The most likely place where quarantine may successfully and profitably be established seems to be in isolated hill tracts where efforts are being made to establish new temperate fruit and vegetable crops or to extend their cultivation. It is exactly in these crops that our knowledge of distribution is most lacking. The case of *Botryosphaeria ribis* causing the die-back disease, and *Venturia* causing scab of apples are cases where quarantine legislation might be valuable. There may be others also.

Intensive survey work is being done in Chaubattia (U. P.) and it needs extension to other areas. This is our fundamental requirement in India, and until this is fulfilled we do not seem to be in a position to meet the ' fundamental prerequisites ' outlined by the Plant Board of the United States of America.

Summary

The crops of India may conveniently be divided for quarantine considerations into six categories, as follows :—

(1) The staple foodstuffs (grains and pulses) grown throughout the northern plains and southern lowlands, and to a very small extent in the hills.

(2) The sub-tropical and tropical fruits, with a similar distribution.

(3) Commercial crops of restricted distribution (e.g. jute, tea and coffee) limited by climatic factors.

(4) Commercial crops of wide distribution (e.g. cotton, tobacco and sugarcane).

(5) Temperate crops of restricted distribution (e.g. temperate fruits such as apples, pears and plums) grown in the hills.

(6) Temperate crops of wide distribution (e.g. common European vegetables) grown during the warm weather in the hills and during the cold weather on the plains.

In the absence of any systematic survey data for India, an analysis has been made from various published works which gives the best possible indication of the occurrence in India of sixty-eight diseases of important crops. These diseases are only those which are known to cause severe damage where they occur in India or in other countries. It is found that in thirty-three cases the organisms concerned are widespread throughout India, while at least fourteen more are found almost throughout the narrow geographical limits of the crop concerned. There remain only twenty-one cases in which the records indicate a possibly narrower distribution, though for reasons stated this figure is probably an over-estimation.

In considering the applicaton of quarantine measures the problem has been considered from various aspects. The principles recognised by the National Plant Board of the United States of America have been taken into consideration. These are briefly as follows :—

(1) The pest concerned must offer a threat to substantial interests.
(2) There must be no better substitute for the proposed quarantine.
(3) The objective of the quarantine must be reasonable of expectation.
(4) The economic gains must outweigh the cost of administration.

Adopting these principles, the various crop categories have been considered individually from the point of view of the five types of quarantine action recognised by McCubbin, namely, embargo, detention, disinfection, inspection, and unrestricted entry.

The conclusion reached is that the only strong case for inter-provincial quarantine in India is in the temperate crops of restricted distribution (the temperate fruits of the hills). There may perhaps be one or two special cases in virus diseases of vegetatively propagated crops on the plains, but national regulations are dependent on survey work for which at the present time India has no facilities.

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THE GENUS *FUSARIUM*

IV. INFECTION AND CROSS-INFECTION TESTS WITH ISOLATES FROM COTTON (*GOSSYPIUM* SP.), PIGEON-PEA (*CAJANUS CAJAN*) AND SUNN-HEMP (*CROTALARIA JUNCEA*)

BY

G. WATTS PADWICK

Imperial Mycologist

M. MITRA

Assistant Mycologist

AND

P. R. MEHTA

Formerly Assistant to Imperial Mycologist, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 5 February 1940)

(With Plates XXVIII and XXIX)

Introduction

IN the first paper of this series [Padwick, 1939] it was pointed out that contradictory evidence exists with regard to the ability of the species of *Fusarium* isolated from cotton (*Gossypium* sp.), pigeon-pea (*Cajanus cajan*) and sunn-hemp (*Crotalaria juncea*) to pass from one host to another and bring about infection.

Butler [1918] said ' The pigeon-pea *Fusarium* has not been found on any other plant '. When Vincens [1921] described the wilt disease of *Crotalaria* he said that the organism more closely resembled *F. udum* Butl. than *F. vasinfectum*. Small [1920] made isolations from wilted carnations, *Nigella* and *Delphinium* and found that the fungi isolated could readily cross-infect the three host species. Again the same author [Small, 1922] referred to successful cross-inoculation of *Delphinium* with an organism from cashew (*Anacardium occidentale*). A similar fungus was isolated from *Grevillia robusta* and caused infection of *Grevillia* plants but not of *Eugenia jambos* and *Eriobotrya japonica*, from which isolates of similar appearance were obtained. Pigeon-peas grown in soil known to be infected succumbed to wilt and the *Fusarium* was isolated. It was considered to be *F. udum* Butl. In a later paper Small [1925] related that a *Fusarium* considered to be *F. udum* was found associated with potato-tuber rotting. It was proved to be able to rot potatoes and sweet potatoes. The fungus was also found on wilted beans (*Phaseolus* sp.) but could not reproduce the disease under normal conditions, though it could cause disease under conditions exceptionally favourable for its development. The conclusion was reached that the pathogenicity of *F. udum* ' depends less on the strain of the fungus and the presence of a possible host plant than on the environmental conditions under which the fungus comes into contact with its host '. Hansford [1939] concludes that the

Fusaria associated with wilt diseases of some plants in Uganda are not restricted in pathogenicity to a single species of host.

Mitra [1934] found that *Fusarium vasinfectum* attacking sunn-hemp can attack also pigeon-pea, though not cotton, whereas Uppal and Kulkarni [1937] were unable to infect sunn-hemp with the organism from pigeon-pea or *vice versa*.

It was with a view to throwing light on this controversy that isolations and cross-inoculation studies were made. These are described in this paper.

Material

For the purposes of this study infected material was obtained from wilted cotton seedlings from Parbhani (Hyderabad, Deccan) ; from wilted pigeon-pea from Pusa (Bihar), Rudroor (Hyderabad, Deccan) and Cawnpore (U. P.) ; from wilted sunn-hemp from Pusa (Bihar) and Cawnpore (U. P.). Cultures of *Fusarium vasinfectum* from cotton and from sunn-hemp were kindly supplied by Dr B. N. Uppal, Plant Pathologist to the Government of Bombay.

Experimental

The isolations were made during a period of sixteen months, and it was only towards the end of this period that a standardised method of isolating and recording the results was adopted. Thus for a few of the isolates studied data are incomplete as to the number of pieces of tissue plated out and the number of similar isolates obtained. Some of the earlier isolates were made from comparatively superficial tissue of the wilted plants, whereas at the later dates not only the bark but a deep layer of the cortex was removed and only the innermost woody tissues were taken for plating. In the earlier isolates the method of isolation was immersion of the tissue in 0·1 per cent mercuric chloride solution for two minutes followed by washing in alcohol, whereas later the pieces were immersed for two minutes in one per cent silver nitrate solution and then dipped in two per cent sodium chloride solution in order to deposit the silver as chloride.

Three experiments in all were conducted. The first and second were done in 1938, and were merely preliminary tests of pathogenicity of the early pigeon-pea isolates on pigeon-pea and sunn-hemp isolates on sunn-hemp respectively. The third experiment was made in 1939. By this time fifty-one representative isolates had been selected for the study and all these isolates were tested for infectivity of cotton, pigeon-pea and sunn-hemp. The method used in this experiment will here be described in detail and apart from minor points the same method was used for the first two experiments.

Single-spore cultures of certain of the isolates were obtained by marking the single spores in dilution plates and removing them when they had germinated. The cultures were grown on a sterilized mixture of ten parts cornmeal, ninety parts soil and thirty parts water in Erlenmeyer flasks. The soil was inoculated on June 26th and 27th, 1939, and the fungus allowed to grow until July 19th, when the soil was removed from the flasks, after making brief notes on the amount of growth of each isolate. This growth was recorded as follows :—

Poor (very little penetration of soil).

Moderate (mycelium apparently grown about half-way through the soil).

Good (most of the soil ramified by mycelium).

Excellent (soil completely ramified by mycelium).

The soil in all the flasks of one isolate was thoroughly mixed.

Soil sufficient for 620 eleven-inch earthenware flower-pots, prepared by mixing one load of well-rotted cowdung with five loads of silty Delhi soil was sterilized in autoclaves at 20 lb. per square inch pressure on July 17th to 20th. After thorough mixing it was placed in the pots.

In each pot 150 gm. of inoculum were spread on the surface of the soil, except with cultures F 25, F 152 and F 6, of which the quantities were respectively 125, 130 and 125 gm. only, due to rejection of certain contaminated flasks. In this way twelve pots were infested with each organism, sufficient for four pots each of cotton, sunn-hemp and pigeon-pea. In addition there were, as controls, forty-eight pots (sixteen for each host) of similarly sterilized soil to each of which was added 150 gm. of sterilized maize-meal-soil mixture without any organism. Eight seeds of cotton (Malvi 9, kindly supplied by the Botanist, Institute of Plant Industry, Indore), pigeon-pea (I. P. Type 5) and sunn-hemp (a local variety from Pusa) were placed in their respective pots (four replicates of each culture and sixteen controls) and were covered with sterilized soil. All the host varieties used are known to be highly susceptible to wilt.

The first wilted cotton plant appeared on August 16th, twenty-seven days after sowing. The first appearance of wilt in pigeon-pea was on August 2nd when the seedlings were only thirteen days old, and in sunn-hemp on August 7th when the seedlings were eighteen days old. For several weeks the development of wilt was slow, but gradually increased until on September 11th the maximum was reached with fifty-one plants wilting on that day. After September 20th wilting fell off rapidly so that in the first week of October only thirty-four plants wilted. Owing to the large size of the plants at this time they showed signs of crowding in the pots and the experiment was discontinued on October 10th. Each day as the wilted plants were observed they were kept and numbered for the purpose of isolation.

The methods used in the first two experiments differed from those in the third mainly as regards the following :—

(1) Only six-inch pots were used, with six seeds in each, but there were six replicates.

(2) Prior to sowing the seeds were sterilized with formalin. After some deliberation this was not done in the third experiment owing to the possible danger of interfering with germination.

The results of these experiments are summarized in Table I. The host and locality are listed, together with the number of morphologically similar isolates and the total number of isolates of *Fusarium*. It is also stated whether the cultures were obtained from single spores. In columns 8-13 will be found the total number of seedlings which germinated and the number of plants which wilted in the third experiment, while in parenthesis the results of the first and second experiments are given. The amount of growth noted in the flasks is also given in Table I.

TABLE I

Pathogenicity of isolates of Fusarium *from pigeon-pea, cotton and sunn-hemp in cross-inoculation tests*

Culture	Host	Locality	Single-spore (SS) or mass (M) culture	Number of similar isolates	Total number of *Fusarium* isolates	Condition of growth in flasks	Pathogenicity*					
							Cotton		Pigeon-pea		Sunn-hemp	
							Seeds germinated	Plants wilted	Seeds germinated	Plants wilted	Seeds germinated	Plants wilted
F 25	Cotton	Bombay : Supplied by Dr B. N. Uppal	...	...	...	Poor	19	4	32 (36)	1 (0)	31	0
F 88	,,	Parbhani, Hyderabad (Deccan)	M	21	21	Excellent	15	1†	32	0	29	1†
F 96	,,	,,	M	...	...	,,	23	1†	22	0	29	0
F 97	,,	,,	M	...	...	Moderate	18	0	31	0	31	0
F 140	,,	,,	M	1	1	Excellent	5	0	1	0	30	0
F 141	,,	,,	M	1	1	Moderate	3	0	32	0	23	0
F 142	,,	,,	M	2	3	,,	12	1†	32	0	10	0
F 143	,,	,,	M	1	3	Good	11	0	31	0	32	0
F 144	,,	,,	M	1	3	Moderate	11	0	31	0	26	0
F 145	,,	,,	M	1	3	,,	22	2†	32	1	32	0
F 147	,,	,,	M	5	5	Poor	23	18	31	0	30	0
F 148	,,	,,	M	1	1	Excellent	17	0	8	2†	31	0
F 149	,,	,,	M	1	3	,,	17	0	5	0	32	0
F 150	,,	,,	M	2	3	,,	8	0	10	0	30	0
F 152	,,	,,	M	1	2	Good	26	0	31	0	31	0
F 153	,,	,,	M	1	2	Moderate	0	0	17	0	2	0
F 154	,,	,,	M	2	2	,,	20	0	32	1	31	0
F 1	Pigeon-pea	Pusa, Bihar	SS	...	...	,,	15	0	13 (35)	0 (0)	31	0
F 2	,,	,,	SS	...	...	Poor	20	0	32 (33)	26 (17)	32	0

F 3	,,	,,	SS	...	...	Moderate	18	0	31 (26)	3 (0)	30	0
F 4	,,	,,	SS	...	...	,,	21	0	32 (17)	0 (7)	29	1
F 5	,,	,,	M	3	16	Poor	26	0	32 (36)	25 (32)	28	0
F 6	,,	,,	M	7	16	,,	25	0	32 (35)	31 (32)	29	0
F 7	,,	,,	M	1	16	,,	24	0	32 (35)	30 (27)	30	0
F 8	,,	,,	M	8	16	...	...	...	— (15)	— (0)	...	...
F 9	,,	,,	M	1	16	Moderate	19	0	31 (8)	1 (0)	31	0
F 10	,,	,,	M	2	16	Poor	24	0	32 (33)	32 (25)	30	1
F 11	,,	,,	SS	5	5	,,	22	0	31 (34)	26 (32)	30	5 (In one replicate only)
F 12	,,	,,	SS	4	6	,,	19	0	32 (32)	27 (31)	30	2
F 59	,,	Rudroor, Hyderabad (Deccan)	M	6	6	,,	24	0	32	10	30	0
F 137	,,	Pusa, Bihar	SS	10	10	Moderate	21	0	32	32	32	3
F 138	,,	,,	SS	7	8	Excellent	23	0	32	0	31	0
F 139]	,,	,,	SS	1	8	Poor	23	0	32	29	29	0
F 164	,,	Cawnpore, U. P.	SS	10	10	Moderate	23	0	32	30	31	2
F 165	,,	,,	SS	10	10	,,	21	0	32	26	30	2
F 171	,,	Pusa, Bihar	SS	10	10	,,	28	0	32	31	31	0
F 172	,,	,,	M	10	10	Poor	21	0	32	32	32	0
F 173	,,	,,	SS	9	9	,,	26	0	32	32	32	0
F 174	,,	,,	SS	10	10	,,	21	0	31	26	30	0
F 175	,,	,,	SS	10	10	,,	24	0	32	24	30	2
F 176	,,	,,	SS	10	10	,,	19	0	32	30	31	1
F 13	Sunn-hemp	,,	M	1	21	,,	20	1†	31	31	32 (36)	1 (0)
F 14	,,	,,	M	9	21	Moderate	19	0	31	1	31 (31)	0 (0)
F 15	,,	,,	M	2	21	,,	20	0	32	30	32 (36)	1 (0)
F 17	,,	,,	M	3	21	...	...	...	...	...	— (29)	— (13)

* Figures in parenthesis refer to experiments 1 and 2.
† Symptoms not quite typical of *Fusarium* wilt.

TABLE I—*concld.*

Culture	Host	Locality	Single-spore (SS) or mass (M) culture	Number of similar isolates	Total number of *Fusarium* isolates	Condition of growth in flasks	Pathogenicity					
							Cotton		Pigeon-pea		Sunn-hemp	
							Seeds germinated	Plants wilted	Seeds germinated	Plants wilted	Seeds germinated	Plants wilted
F 18	Sunn-hemp	Pusa, Bihar	M	4	21	Poor	23	0	32	2	32 (35)	10 (11)
F 19	,,	,,	SS	3	3	Good	20	0	32	0	27 (31)	6 (18)
F 26	,,	Bombay : Supplied by Dr B. N. Uppal	...	...	...	Poor	20	0	32 (36)	0 (0)	32 (32)	14 (12)
F 166	,,	Cawnpore, U. P.	SS	10	10	Moderate	20	0	32	0	30	23
F 167	,,	,,	SS	1	1	Excellent	23	0	32	0	31	7
F 168	,,	Pusa, Bihar	SS	10	10	Moderate	24	0	32	0	30	23
F 169	,,	,,	SS	1	2	Excellent	24	0	32	0	31	9
F 170	,,	,,	M	1	2	,,	17	0	11	0	30	5
Control	...	...	...	...	...	...	71	1	126 (77)	2 (0)	118 (41)	4 (0)

General view of cross-inoculation experiment with isolates of *Fusarium* from cotton, pigeon-pea and sunn-hemp

The effects of several isolates of *Fusarium* on germination of cotton, pigeon-pea and sunn-hemp seeds

FIG. 1. *Fusarium* No. 140

FIG. 3. *Fusarium* No. 153

FIG. 2. *Fusarium* No. 141

FIG. 4. Control

Plate XXVIII illustrates the general lay-out of the main experiment, and Plate XXIX shows a closer view of some of the series in infested soil, illustrating clearly the inhibition of germination.

TABLE II

Summary of infection levels in the wilt-producing organisms

Culture	Isolated from	Cotton plants wilted	Pigeon-pea* plants wilted	Sunn-hemp* plants wilted	Growth of fungus in flasks of soil
F 147	Cotton	18	0 (17)	0	Poor
F 2	Pigeon-pea	0	27 (17)	0	,,
F 5	,,	0	25 (32)	0	,,
F 6	,,	0	31 (32)	0	,,
F 7	,,	0	30 (27)	0	,,
F 10	,,	0	32 (25)	1	,,
F 11	,,	0	26 (32)	5 (In one replicate only)	,,
F 12	,,	0	27 (31)	2	,,
F 59	,,	0	10	0	,,
F 137	,,	0	32	3	Moderate
F 139	,,	0	29	0	Poor
F 164	,,	0	30	2	Moderate
F 165	,,	0	26	2	,,
F 171	,,	0	31	0	,,
F 172	,,	0	32	0	Poor
F 173	,,	0	32	0	,,
F 174	,,	0	26	0	,,
F 175	,,	0	24	2	,,
F 176	,,	0	30	1	,,
F 13	Sunn-hemp	1	31	1 (0)	,,
F 15	,,	0	30	1 (0)	Moderate
F 17	,,	..	..	13	
F 18	,,	0	2	10 (11)	Poor
F 19	,,	0	0	6 (18)	Good
F 26	,,	0	0 (0)	14 (12)	Poor
F 166	,,	0	0	23	Moderate
F 168	,,	0	0	23	,,
		Doubtful cases			
F 25	Cotton	4	1 (0)	0	Poor
F 3	Pigeon-pea	0	3 (0)	0	Excellent
F 4	,,	0	0 (7)	1	Moderate
F 167	Sunn-hemp	0	0	7	Excellent
F 169	,,	0	0	9	,,
F 170	,,	0	0	5	,,

* Figures in parenthesis refer to experiments 1 and 2.

Conclusion

The major experiment, on which our conclusions must largely be based, involved the use of fifty-one cultures, some hundreds of flasks, and over 600 pots containing in all about four tons of soil which had to be sterilized. Once completed there were numerous ways in which contamination from pot to pot could take place—by water, animals, birds and insects, and workers' hands to mention only a few. Precautions were taken to reduce these to a minimum. Taking into account these various possible sources of error the number of wilted plants appearing in the controls can be considered very low.

Considering the results first in a quite general way, we find that of the sixteen isolates from cotton seedlings from Hyderabad, only one caused wilt but a number of them prevented normal germination. It is noteworthy that the various isolates showed different tendencies in this respect. For example F 140 practically inhibited germination of cotton and pigeon-pea ; F 142 severely reduced germination of cotton and sunn-hemp but had no deleterious effect on pigeon-pea ; while F 153 reduced the germination of all three. None of the isolates which produced this harmful effect on germination appeared capable of causing wilt at a later stage.

Owing to a certain number of wilted plants appearing in the controls it is necessary to take a safe margin of percentage infection as an indisputable proof of pathogenicity. It is therefore proposed to accept ten or more wilted plants as a reliable indication of ability of the fungus to produce wilt. Less than ten wilted plants may be regarded with a certain amount of reservation, while cases with two plants or less may be disregarded entirely. Adopting this procedure we are able to list the cases of proved pathogenicity and the doubtful cases, together with the number of plants wilted and the condition of growth of the fungi in the flasks of soil. We thus get in Table II a brief summary of the salient points of Table I.

It is very clear that the most pathogenic isolates are almost, if not entirely, restricted to one host. Curiously enough, it happens that two isolates, F 13 and F 15, obtained from sunn-hemp, produced only a wilt of pigeon-pea. These two isolates were obtained from the same group of plants as F 17 and F 18, both of which produce only wilt of pigeon-pea. These particular isolations were made before the technique had been perfected and it is quite possible that they may have come from the superficial cortical tissue. One can easily see how, with a mass culture, one might obtain both strains from such tissue as a mixture. Both the pigeon-pea and sunn-hemp pathogens might readily be obtained together in cultures and might be expected to infect both hosts. Thus we have one possible explanation of the divergence of results obtained by various workers, some of whom have found the pigeon-pea and sunn-hemp organisms highly specific whereas others have found that they possess an infective range of several hosts.

One other curious and highly interesting observation may be made here. It will be seen that the highly pathogenic forms made poor or, at best, moderate growth on the mixture of soil and cornmeal used as inoculum. On the other hand, the organisms which caused a much lower percentage of wilting grew well in the flasks, all three of the less effective sunn-hemp organisms

having ramified the soil and producing considerable ærial mycelium. The full significance of these facts will become clear in the next contribution of this series which will, to a large extent, resolve the confusion at present existing with regard to the taxonomy of these fungi.

SUMMARY

1. Cultures of *Fusarium* were isolated from cotton (*Gossypium* sp.), pigeon-pea (*Cajanus cajan*) and sunn-hemp (*Crotalaria juncea*). Fifty-one such isolates were tested for their pathogenicity against all three hosts.

2. Most of the cotton isolates failed to cause wilt, but a number of them caused low germination by attacking and destroying the seeds. Some isolates produced this effect on cotton, others on pigeon-pea, and yet others on sunn-hemp or on two or three of these.

3. As regards wilt there was a high degree of specificity and few if any cases of wilt resulted from these inoculations. Two isolates from sunn-hemp were specific for pigeon-pea.

4. The isolates causing severest wilting were those which grew least vigorously on the mixture of soil and maizemeal used for infesting the soil.

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SUGARCANE VARIETAL TRIALS IN THE DECCAN CANAL-TRACT AT PADEGAON, 1933-1938

BY

B. P. VAGHOLKAR, L.Ag. (Bom.)

Principal Agricultural Officer, Sugarcane Research Scheme, Bombay-Deccan, Padegaon*

AND

N. B. PATWARDHAN, B.Ag. (Bom.)

Agricultural Overseer

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(With Plates XXX—XXXII and two text-figures)

Introduction

IN India cane is grown under varying conditions of soil and climate either with irrigation or without irrigation but under well-distributed rainfall during a single monsoon or two monsoons. In the Deccan canal-tract, owing to the very scanty rainfall it is grown under irrigation throughout the year and very high yields are recorded.

Before the commencement of the Sugarcane Research Scheme at Padegaon with the munificient grant from the Imperial Council of Agricultural Research, a collection of canes from different parts of the world, like Queensland, Mauritius, Java, Barbados, Hawaii and from India—as Hebbal-Mysore and Coimbatore—was made and grown in the museum for study for a number of years at Manjri, the oldest sugarcane experimental station, near Poona.

Flowering varieties were not much in favour with the cultivators as they failed to supply the green tops, so very necessary for feeding the bullocks used for crushing the cane, in the course of *gul* manufacture. Some of the flowering varieties—like Manjav (B 376), D 109, J 213, J 36, Str. D 109, B 208, B 1528, H 109, HM 337 and the non-flowering canes HM 544, HM 310, HM 89—were under final trial at Manjri as well as at the two substations at Baramati and Kopergaon on the Deccan canals.

The varietal trials till 1925 have been well described by Patil and Patwardhan [1925]. Subsequent to 1925, the varieties POJ 2878 and EK 28 were brought under trial and after four years' testing, the variety POJ 2878 was supplied to the Belapur Sugar Factory and EK 28 was introduced among the cane-growers.

Out of these varieties, only D 109, HM 544 and HM 89 spread a little among the cultivators till the introduction of EK 28 and POJ 2878 in 1931. These varieties being of rather high fibre-content spread mostly among the cultivators with power crushers.

From this period onwards, with the passing of the Tariff Act by the Government of India, the aspect however changed owing to the rapid springing

* This scheme is partly subsidised by the Imperial Council of Agricultural Research.

up of the sugar factories. The breeding work on the noble canes which was started at Coimbatore in 1926 had also evolved a number of selections with promise of success. Hence the selection work described in this paper comprises trials both for the factories and the cultivators.

Soil

Padegaon Sugarcane Research Scheme is situated on the Nira Right Bank Canal in Satara district, about forty five miles from Poona on the old Poona-Satara Road, elevation above sea-level being 1804 ft. The soil belongs to the group of black cotton soil which is further classified by Basu and Sirur [1938] by the modern genetic method into distinct types. The soil of the farm falls under the type ' B ', and is described as follows :—

> 'Dark grey soil rich in clay up to a depth of two feet overlying a layer with lighter texture interspersed with patches of brown material, extending up to about four feet. Below this is a brownish red horizon with similar texture with concretions of calcium carbonate and silicates. This layer varies in depth and usually goes up to murum.'

The sub-soil water-level is found to fluctuate between 6 and 10 ft.

Meteorology

Average rainfall of the place is only 18 in. but most of it comes in September and October. There is also a great variation from year to year as has been shown in Table I. The highest maximum and the lowest minimum temperatures ever reached within the five years are 109°F. and 37·5°F. respectively with the average wind velocity of 7·34 miles per hour from April to September (the maximum being 9·05 miles per hour in May) within which period it is at its maximum. Full data for five years are graphically illustrated in Figs. 1 and 2.

Owing to sporadic nature of rainfall distribution and its insufficient quantity, the cane is required to be grown with irrigation water from canals from the time of planting till harvest, during which period nearly thirty-four to thirty-five irrigations at ten-day interval are to be given. In spite of this controlled irrigation, it is traced that deviation in climate does influence cane-growth and in the end affects the yield. In Northern India and the United Provinces the critical periods are (1) hot summer and (2) winter, characterised by want of moisture in the former and by frost in winter of varying degrees in rigours, as the crop there is mainly rain-fed. But under Padegaon conditions the critical periods occur during monsoon when the growth-period of cane is spread, and are dependent upon rainfall, specially its distribution which influences humidity required for growth during the period. These periods can be grouped into three distinct ones and their normal characteristics are enumerated below :—

(1) First period—Mid-May to June :
Characterised by ante-monsoon showers in May followed by normal weather in June, quantity of rainfall is of no consideration.

(2) Second period—July and August :
Characterised by small quantities of rainfall in which case its long range distribution is an important factor as against quantity.

(3) Third period—September :
Characterised by sultry climate precursory to rain and high rainfall.

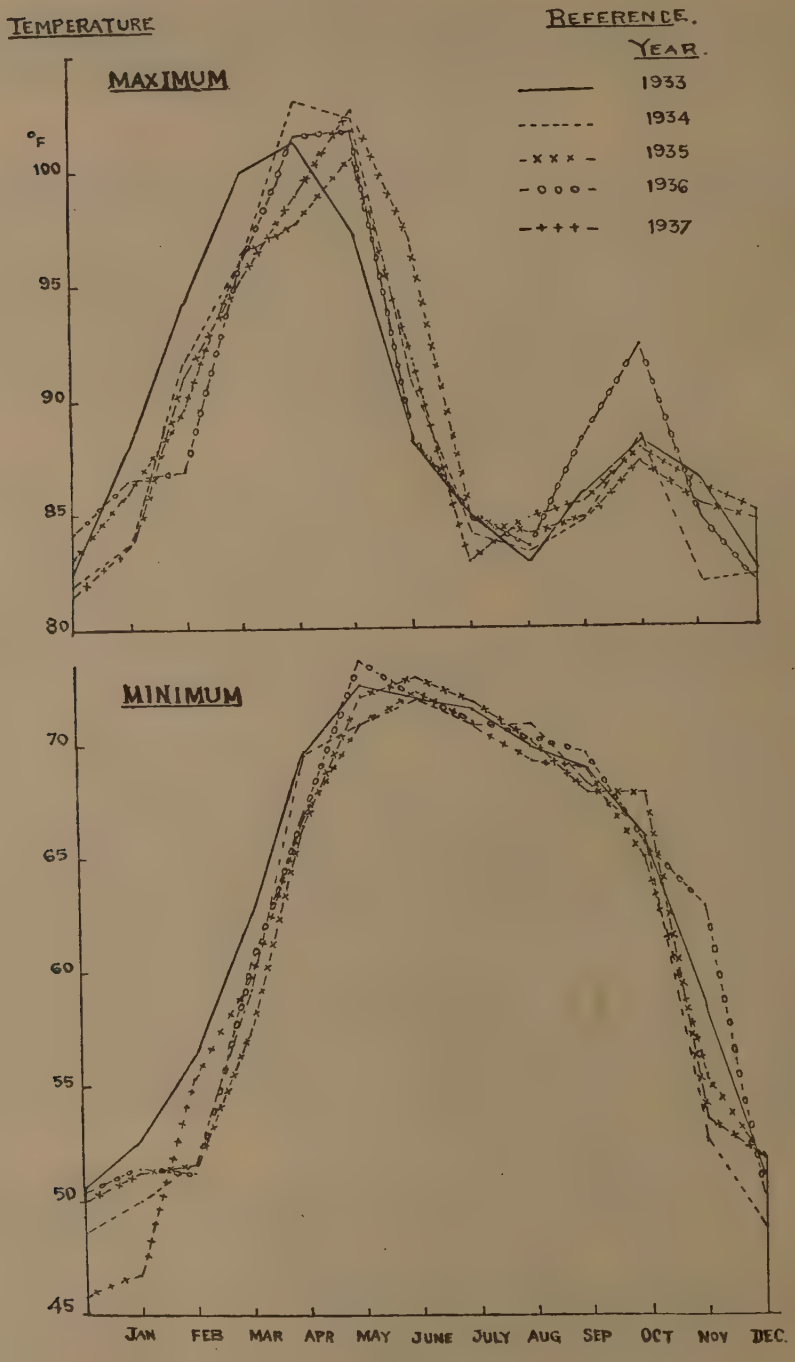

FIG. 1. Meteorological data (temperature), 1933-37

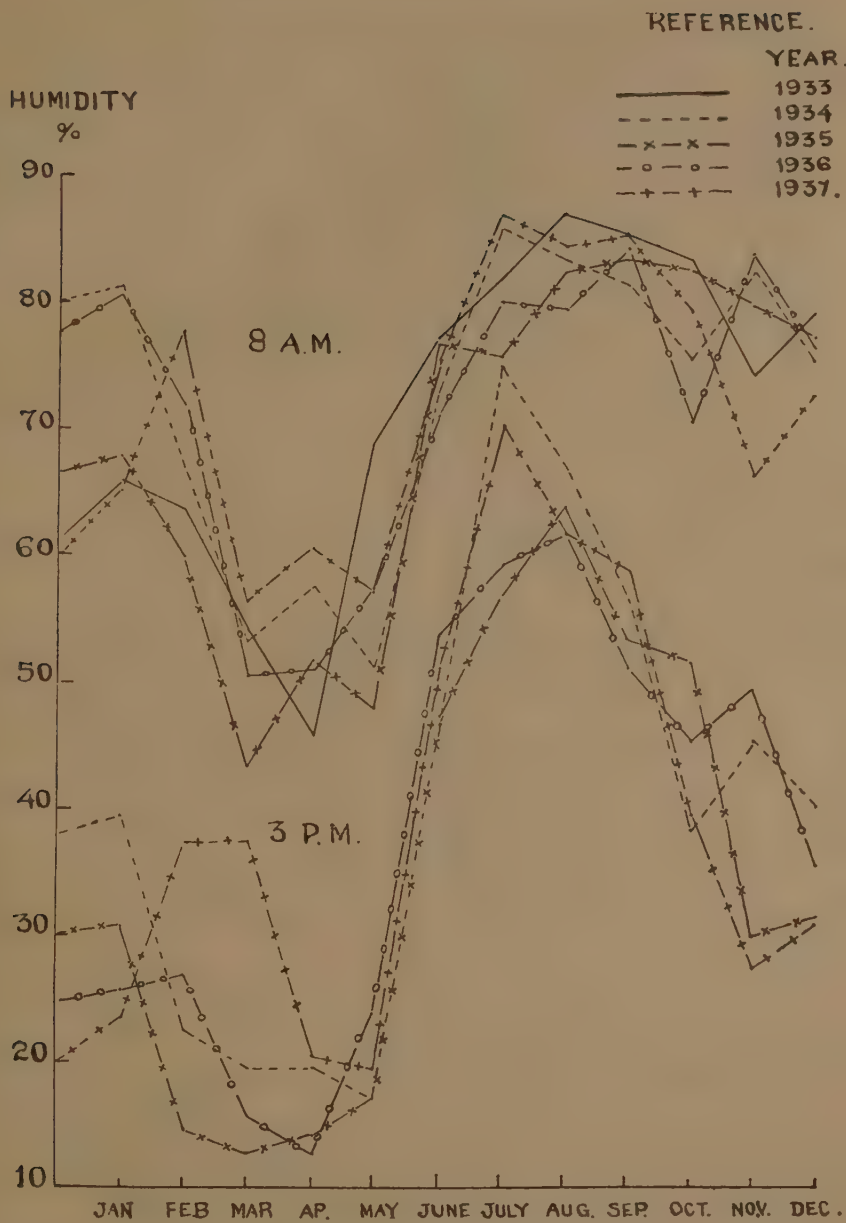

Fig. 2. Meteorological data (humidity), 1933-37

TABLE I

Rainfall and number of rainy days (1933-37)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
						Rainfall in inches							
1933	..	..	0·18	..	0·94	2·74	2·60	3·66	4·69	1·30	1·07	0·75	17·93
1934	..	..	0·18	0·66	1·27	3·57	1·84	1·16	2·70	4·06	5·57	..	21·01
1935	..	..	..	..	..	2·66	0·90	6·47	1·37	6·60	..	0·36	18·36
1936	..	0·26	1·75	..	2·43	2·01	0·14	0·77	4·58	0·05	1·92	..	13·91
1937	..	0·21	..	1·92	0·22	2·78	3·47	0·28	8·59	2·49	..	0·46	20·92
						No. of rainy days							
1933	..	..	2	..	5	13	10	11	14	11	5	2	73
1934	..	..	1	3	2	10	16	10	6	7	3	..	58
1935	..	..	..	..	..	10	8	11	5	14	..	1	49
1936	..	1	2	..	4	5	5	8	10	1	6	..	42
1937	..	2	..	3	2	8	18	8	13	7	..	2	63

Materials and methods

During the period from 1931-37, five dozen thick and thin seedling canes were received from Coimbatore and half a dozen from Hebbal-Mysore. These formed the basis of selection work and the promising selections, details of which are given in the subsequent pages, have been obtained from this collection.

The work of selection, in the preliminary, prefinal and final varietal trials had to be expedited in order to enable early release of these varieties for testing with the cultivators and the factories in different soil types. The following policy was adopted.

(*a*) When the varieties were received, these were multiplied in the first year, tested in prefinal trial for a year or two during which period they acclimatized ; and if during this period any variety showed outstanding performance, it was taken into final trial.

(*b*) In the final trial the prominent varieties were tested with control varieties like Pundia, POJ 2878 and EK 28, both from sugar and *gul* point of view in replicated trials. In all the trials at Padegaon the manurial dose of 150 lb. nitrogen is maintained. Three years' period was fixed for a thorough trial but if it was traced that even within two years any one showed outstanding superiority over the control ones it was liberated for multiplication and trials outside.

The following were the criteria for selecting a variety for the Deccan conditions and any variety which stood to these criteria, was finally selected for liberation for trials outside :

(1) Good germinative capacity.
(2) Stooling capacity and character of resisting adverse season.
(3) A fair immunity to pests and diseases.
(4) Tendency to less shooting and forming pith incident to arrowing.
(5) Efficient root-system from the stand-point of securing maximum value from fertilizers applied to the land.
(6) Ease of stripping or trashing.
(7) Early or late maturity and keeping quality in the field after maturity.
(8) High sucrose.
(9) High tonnage.

Experimental

The varietal trials in the following pages have been classified into four experiments as below :—

Experiment I : Medium-late varietal trials, 1933-34 to 1935-36.
Experiment II : Medium-late varietal trials, 1935-36 to 1937-38.
Experiment III : Early varietal trials including sugarcane-sorghum hybrids, 1934-35 to 1936-37.
Experiment IV : October planting trials, 1934-35 to 1936-37.

Experiment I

Trial of medium-late varieties, 1933-34 to 1935-36

In this three-year period, the control varieties grown alongside with other varieties were Pundia, POJ 2878 and EK 28 ; the first of these control

varieties is the non-flowering, cultivator's favourite cane for *gul*-making and the latter two flowering are mainly factory canes with high sugar content.

Year 1933-34.—This was the first year of trial; from amongst the first two batches of Co varieties (viz. Cos 358 to 365 except Co 359 and Cos 400 to 415) the varieties Co 360 and Co 402 which showed promise from only growth characters were taken together with the new addition of HM 320 from Hebbal-Mysore. In addition to these, the varieties Co 290, HM 89, Str. D 109 and H 109 which had shown good performance at Manjri Farm were also included. All these are flowering varieties except HM 89 and HM 320.

The old canes Str. D 109, H 109 and HM 89 fared badly in comparison with the new arrivals; the first two show abnormal fluctuation in germination from season to season and have low sugar content. HM 89 produces abnormal bunches of tillers which exercise a check on normal cane growth, but it is a cane of high sugar content and for specific tracts.

Year 1934-35.—The varieties H 109 and Str. D 109 were therefore discontinued. Among the other varieties, Co 360 has equalled POJ 2878 in yield as in the previous year. Co 402 has extreme fluctuation in flowering from year to year, which has been reflected in its yields; yet it issignificant over EK 28.

Year 1935-36.—HM 89 is dropped as it had a thorough trial for a long period at Manjri (for seven years) and even at Padegaon. The only new additions are Co 419, Co 413 from early group and Co 412. Among the varieties tried during the last two years, HM 320 has shown highly significant performance over the control varieties; whilst Co 360 and Co 290, even though not surpassing POJ 2878, have again shown significantly high yields over EK 28 and Pundia.

The three years' data of cane and commercial cane sugar per acre is presented in Table II year by year. In the following pages, commercial cane sugar has been arrived at as per formula recommended by the Director, Imperial Institute of Sugar Technology, which is reproduced below for ready reference :—

$$\text{C. C.} = \frac{3\,P}{2}\left(1 - \frac{10+F}{100}\right) - \frac{B}{2}\left(1 - \frac{6+F}{100}\right)$$

Where P = Polarisation in first expressed juice.

B = Brix in first expressed juice.

F = Fibre in cane.

The varieties Co 290, Co 360, Co 402 and HM 320 have completed the three years' test in the final trial in comparison with the three control varieties, POJ 2878, EK 28 and Pundia.

Some of these promising varieties have been illustrated in Plates XXX and XXXI.

Detailed studies were carried out with regard to these varieties from standpoint of their developmental characters and these are discussed below.

Co 290 Co 360 Co 412 Co 413 Co 414 Co 419 POJ 2878 Pundia EK 28

January planting : age of crop $10\frac{3}{4}$ months

Co 416 Co 417 Co 421 Co 426 HM 320 POJ 2878 Pundia EK 28

January planting : age of crop $10\frac{3}{4}$ months

TABLE II

Yield of millable cane and commercial cane sugar in tons per acre
(Data for three seasons)

	Name of variety										General mean	S. E. of treatment mean	Whether general effect of treatment significant by *z*-test	Critical difference for significance
	Co 290 (tons per acre)	Co 360 (tons per acre)	Co 402 (tons per acre)	HM 320 (tons per acre)	POJ 2878 (tons per acre)	EK 28 (tons per acre)	Pundia (tons per acre)	HM 89 (tons per acre)	H 109 (tons per acre)	Str. D 109 (tons per acre)				
1933-34														
Cane	42·54	36·72	43·59	39·86	36·61	30·07	37·96	26·97	31·07	38·90	35·85	2·42	Significant	6·74
C. C. sugar	5·22	5·29	4·38	4·17	5·31	3·88	4·48	3·83	3·80	3·92		Not calculated statistically		
1934-35														
Cane	42·68	40·53	36·48	47·13	40·72	30·97	29·44	38·39			38·30	2·01	Significant	5·55
C. C. sugar	5·32	4·89	3·96	5·72	5·67	4·39	3·91	5·63				Not calculated statistically		
1935-36														
	Co 290	Co 360	Co 402	HM 320	POJ 2878	EK 28	Pundia	Co 412	Co 413	Co 419				
Cane	42·75	40·47	47·61	46·43	44·07	36·59	33·81	34·65	46·89	56·20	42·95	1·42	Significant	3·98
C. C. sugar	5·39	5·56	4·27	5·42	6·33	5·21	4·06	4·33	5·99	7·16		Not calculated statistically		

Conclusions:—1933-34—Co 402 Sig. > POJ 2878, EK 28
1934-35—H M 320 Sig. > POJ 28 8. Co 290 > POJ 2878=Co 360 Sig. > EK 28 and Pundia
1935-36—Co 419 Sig. > Co 402, Co 413 Sig. > Co 290, Co 419, Co 413, HM 320 Sig. > E K 28 and Pundia

Germination.—The new Co varieties have not shown much superiority in germination over the control varieties (Table IV). Rege and Wagle [1939] have shown the deleterious effect of minimum temperature below 50°F. on the rapidity of germination and these temperatures were prevalent during the first three weeks of the seasons 1934 and 1935. As a result of this, the total germination during both these years was retarded.

Borer attack.—The chief pest of the Deccan is a sugarcane borer (*Argyria sticticraspis*) ; the infestation is the highest in April and May. The incidence of the pest as recorded in different varieties in May shows that the varieties Co 290, Co 360 and HM 320 are comparatively more resistant to the attack than EK 28 and Pundia.

Mealy bug is the pest second in importance ; its presence is restricted only to the variety Co 360 which has closely adherent leaf sheaths.

Periodical changes in tillering.—Table III shows the progressive increase in the number of tillers from eighth week till harvest for a four-cent plot (1/25th of an acre) wherein 1200 buds were planted (equivalent to 30,000 buds per acre).

TABLE III

Total shoot counts

(Average of 6 plots, each plot = 4 cents)

Average of two years

Variety	At 8 weeks (germination)	Before earthing up (5½ months)	After earthing up		At harvest		
			7½ months	Percentage of success on before earthing-up count		Percentage of success on before earthing-up count	Tons of cane per acre
Co 290 .	665	3836	1998	52·1	1833	47·8	42·7
Co 360 .	563	1830	1342	73·3	1256	68·6	40·5
Co 402 .	726	3867	1605	41·5	1311	33·9	42·0
HM 320 .	702	2750	1412	51·3	1016	36·9	46·7
POJ 2878	780	2362	1445	61·2	1280	54·2	42·4
EK 28 .	689	1881	1026	54·4	852	45·3	33·8
Pundia .	617	2135	1234	57·8	900	42·1	31·6

The data in Table III, when reduced to the number of shoots obtained per 100 planted buds (Table IV) at different periods, clearly reveal the

situation regarding high or low tillering, and its success at harvest time obtaining in the different varieties. Table IV also shows the percentage of borer-attack.

TABLE IV

Germination and borer attack per cent and ratio of number of shoots on 100 planted buds

Variety	Germination per cent at 8 weeks	Borer attack per cent	Before earthing up	After earthing up	At harvest
Co 290 . .	55·4	4·5	319·7	166·5	152·7
Co 360 . .	46·9	7·2	152·5	111·8	104·7
Co 402 . .	60·5	4·2	322·2	133·7	109·2
HM 320 . .	58·5	5·9	229·2	117·7	84·7
POJ 2878 .	65·0	5·3	196·8	120·4	106·7
EK 28 . .	57·4	10·9	156·7	85·5	71·0
Pundia . .	51·4	11·9	177·9	102·8	75·0

The tables reveal the following special features in tillering :—

(1) High, medium and low tillering in the different varieties.

(2) Maximum and minimum losses of tillers after earthing-up.

(3) Similar maximum and minimum losses between the two periods — after earthing up and at harvest.

All these three will greatly influence the utilisation of manure at different stages, and where the bill of manuring is high this type of information is very important.

It would thus be seen that the production of a large number of tillers as in Co 402 would not be the main criterion for judging the suitability of any variety, but the final successful tillers, coupled with individual weight per cane, would also require consideration. Thus varieties with even mediocre number of canes at harvest coupled with good yields as in Co 360 and POJ 2878 would be efficient varieties although they may be low in tillering.

Next in order will be the variety which gives high tillering with as high a yield as the variety in the first group, although the percentage success of tillers produced may be low. From both these standpoints, the best varieties are Co 360 and POJ 2878 and next to these are Co 290, Co 402 and HM 320. So far as EK 28 and Pundia are concerned, they do not come up to the standard of both of these, as they possess both low tillering capacity and yield.

Habit.—The varieties Co 360 and Co 290 are found to possess very good habit of growth being erect to slightly sub-erect ; so are the varieties POJ

2878 and EK 28. The varieties HM 320 and Pundia were found to be sub-erect to slanting, the variety Co 402 being much more slanting and reclining than others.

With very vigorous growth, the varieties Co 360 and Co 402 tended to lodge in varying intensities, owing only to cyclonic effects which occur specially in September when they have attained the maximum growth. As compared to other varieties, Co 360 was found to be difficult for stripping owing to adherence of sheaths.

Flowering.—Out of the total number of millable canes obtained in each of the different varieties, the number of flowering canes varies with the different varieties. The percentage of flowering canes in the different varieties, as recorded in the year 1935, is given in Table V.

TABLE V

Flowering data

Serial No.	Variety	Percentage of flowering	
1	Co 290	61·9	
2	Co 360	73·5	
3	Co 402	16·3	Recorded on 23rd December 1935
4	HM 320	Non-flowering	
5	POJ 2878	84·9	
6	EK 28	85·4	
7	Pundia	Non-flowering	

Root-system.—The root-exposure studies of the different varieties have shown that excepting Co 360 and Pundia most of them have an efficient root-system having good penetration and lateral spread. Pundia especially has the most superficial and smallest volume of root-system of all the varieties studied.

March of ripeness.—Table VI show the data of brix and purity from October to March, month by month.

The data in Table VI when briefly summarised show the position in regard to the different varieties as to when the ripeness commences and the duration over which it is maintained (Table VII). Information regarding the average weight per cane and sucrose and fibre per cent in cane is also included in Table VII.

TABLE VI

March of ripeness

Month	Co 290		Co 360		Co 402		HM 320		POJ 2878		EK 28		Pundia	
	1934	1935	1934	1935	1934	1935	1934	1935	1934	1935	1934	1935	1934	1935
						Brix								
October	16·13	15·26	18·47	14·73	15·20	12·61	15·26	12·16	18·17	15·38	16·35	16·73	13·39	11·96
November	18·17	18·81	19·91	16·84	17·18	14·10	17·32	14·19	20·25	18·42	18·16	18·86	15·39	12·58
December	20·56	21·27	21·22	18·78	17·18	16·83	18·72	15·42	21·96	21·01	19·22	20·62	17·05	15·32
January	21·35	21·88	22·24	19·58	19·05	17·15	19·07	16·43	22·54	21·97	21·01	21·64	17·93	14·89
February	21·63	21·49	21·74	21·43	18·53	19·36	19·93	17·73	22·24	22·41	21·06	21·28	19·34	18·26
March	21·50	20·43	20·06	19·94	18·37	18·78	20·20	17·56	21·11	21·38	21·46	22·11	20·16	17·63
						Purity								
October	..	75·90	..	75·61	..	70·81	..	61·35	..	74·98	..	82·31	..	61·70
November	..	83·79	..	82·24	..	77·11	..	73·86	..	82·56	..	87·54	..	63·51
December	90·74	88·41	92·53	87·54	88·41	78·66	89·91	79·12	90·22	90·53	92·00	90·86	86·14	75·13
January	89·69	90·36	91·98	90·67	90·69	88·69	91·01	87·40	91·75	92·41	92·30	90·90	89·66	81·25
February	91·16	89·35	91·16	90·72	89·32	91·89	90·20	88·59	91·62	92·51	90·69	91·73	89·48	86·42
March	91·41	87·64	89·71	89·17	88·06	88·82	91·18	87·26	92·02	91·42	92·55	91·81	91·60	85·72

Year 1936-37.—The selections Co 290, Co 360, Co 402 and HM 320 having completed three years' trial were discontinued ; in addition to the varieties mentioned above, five new selections—Co 414, Co 416, Co 417, Co 421 and Co 426—were included (Plate XXXI).

The varieties Co 419, Co 413, Co 416, Co 421 and Co 426 show highly significant yield over the control varieties. Co 416 in spite of its exceptionally high tonnage is traced to be very low in sugar content like Co 402 in experiment I.

Year 1937-38.—The varieties Co 412 and Co 416 were dropped and the remaining varieties were continued. All the Co selections have given significantly higher yield than POJ 2878 and Pundia.

The cane varieties Co 419 and Co 413 have completed three years' trial. The three years' data of cane and commercial cane sugar per acre are presented in Table IX year by year.

As stated above, the cane varieties were studied from standpoint of their developmental characters and these are discussed below.

Germination.—Co 419 gives early and higher germination compared to other varieties. In point of rapid and maximum germination, Co 419 surpasses the control varieties and the next is Co 413.

Borer attack.—The varieties Co 419 and Co 413 have practically the same borer attack as POJ 2878. All these three are more resistent than Pundia. No other pest is present on these varieties (Table XI).

Periodical changes in tillering.—Table X shows the progressive increase in the number of tillers from eighth week till harvest for a four-cent plot (1/25th of an acre), wherein 1200 buds were planted (equivalent to 30,000 buds per acre).

The data in Table X, when reduced to a ratio of number of shoots obtained for 100 planted buds (Table XI) at different periods, clearly reveal the situation regarding high or low tillering, obtaining in the different varieties. Data regarding percentage of germination and borer attack in the different varieties is also given in Table XI.

Rapidity in germination obtained in Co 419 and Co 413 is further reflected in their early and high tillering and also large number of successful canes obtained at harvest compared to the control varieties.

Habit.—Varieties Co 419 and Co 413 possess very good habit of growth, being mostly erect.

Flowering.—The percentage of flowering canes in different varieties as recorded on the 23rd of December 1935 was as shown in Table XII.

Root-system.—Varieties Co 419 and Co 413 have an efficient root-system having both better penetration and lateral spread than POJ 2878. Pundia has the most superficial root-system and the volume of root-system is the least compared to other varieties.

March of ripeness.—Table XIII shows the data of brix and purity from October to March, month by month.

The summary in Table XIV shows when ripeness commences in these varieties and the duration over which the juice-quality is maintained ; the data regarding the average weight per cane, sucrose and fibre-content in cane is also included.

TABLE IX

Yield of millable cane and commercial cane sugar in tons per acre

(Data for three seasons)

	Name of variety										General mean	S. E. of treatment mean	Whether general effect of treatment significant by z-test	Critical difference for significance
	Co 290 (tons per acre)	Co 360 (tons per acre)	Co 402 (tons per acre)	H M 320 (tons per acre)	POJ 2878 (tons per acre)	EK 28 (tons per acre)	Pundia (tons per acre)	Co 412 (tons per acre)	Co 413 (tons per acre)	Co 419 (tons per acre)				
						1935-36								
Cane	42·75	40·47	47·61	46·43	44·07	36·59	33·81	34·65	46·89	56·20	42·95	1·42	Significant	3·98
C. C. sugar	5·39	5·56	4·27	5·42	6·33	5·21	4·06	4·33	5·99	7·16		Not calculated statistically		
						1936-37								
	Co 414	Co 416	Co 417	Co 421	POJ 2878	Co 426	Pundia	Co 412	Co 413	Co 419				
Cane	38·09	50·13	32·56	40·87	28·95	43·19	30·16	32·36	45·86	44·96	38·72	2·08	Significant	5·82
C. C. sugar	5·0	4·36	3·97	4·88	3·99	4·94	3·59	3·59	5·38	6·19		Not calculated statistically		
						1937-38								
	Co 414	Co 419	Co 417	Co 421	POJ 2878	Co 426	Pundia	Co 413						
Cane	37·76	44·58	39·21	41·29	29·38	44·41	24·44	42·57			37·96	2·47	Significant	7·06
C. C. sugar	5·33	6·41	4·86	5·11	4·43	5·36	3·02	5·53				Not calculated statistically		

Conclusions :—1935-36—Co 419 Sig. > Co 402, Co 413 Sig. > Co 290 ; Co 419, Co 413, HM 320 Sig. > EK 28, Pundia
1936-37—Co 416 > Co 413 = Co 419 > Co 426 > Co 421 > Co 414 Sig. > Pundia and others
1937-38—Co 419, Co 426, Co 413, Co 421, Co 414 Sig. > POJ 2878 and Pundia

TABLE X

Total shoot counts

(Average of 6 plots, each plot=4 cents average of three years)

Variety	At 8 weeks	Before earthing up	After earthing up	Percentage of success on before earthing-up count	At harvest	Percentage of success on before earthing-up count
Co 419	900	2946	1855	62·9	1539	52·2
Co 413	892	4047	2076	51·3	1648	40·7
POJ 2878	791	2323	1448	62·3	1195	51·4
Pundia	744	2252	1445	64·2	883	39·2

TABLE XI

Percentage of germination, borer attack and ratio of number of shoots for 10 planted buds

Variety	Germination per cent at 8 weeks	Borer attack per cent	Before earthing up	After earthing up	At harvest
Co 419	75·0	4·4	245·5	154·6	123·2
Co 413	74·3	4·1	337·2	173·0	137·3
POJ 2878	65·9	4·6	193·6	120·7	99·6
Pundia	62·0	8·9	187·7	120·4	73·6

TABLE XII

Flowering data

Serial No.	Variety	Percentage of flowering
1	Co 419	82·4
2	Co 413	80·1
3	POJ 2878	84·9
4	Pundia	Non-flowering

TABLE XIII

March of ripeness

	Co 419			Co 413			POJ 2878			Pundia		
	1935	1936	1937	1935	1936	1937	1935	1936	1937	1935	1936	1937
						Brix						
October	12·59	12·80	16·10	12·86	15·04	17·15	15·38	17·23	17·72	11·96	11·55	14·17
November	15·59	16·83	18·66	15·93	17·83	19·56	18·42	21·29	20·49	12·58	14·01	14·66
December	19·52	18·99	21·40	17·87	19·57	21·10	21·01	21·92	22·28	15·32	15·68	17·66
January	20·21	20·84	21·93	17·04	20·05	21·14	21·97	22·28	22·68	14·89	18·00	18·00
February	21·58	20·63	21·82	18·16	20·43	20·98	22·41	21·19	22·31	18·26	18·64	19·71
March	20·98	20·39	20·35	19·43	19·76	19·45	21·38	22·11	20·55	17·63	20·42	19·40
						Purity						
Octobe	65·86	67·35	79·02	69·97	78·47	84·68	74·98	79·00	82·22	61·70	60·09	75·40
November	77·29	80·39	86·34	81·04	85·13	90·35	82·56	89·60	88·98	63·51	71·24	78·77
December	86·30	83·79	90·35	85·74	88·94	91·81	90·53	90·95	91·62	75·13	75·08	86·92
January	85·49	87·14	90·80	86·06	89·50	92·32	92·41	91·83	90·88	81·25	84·50	87·16
February	91·22	88·37	93·11	88·59	89·30	93·09	92·51	92·10	92·92	86·42	88·47	91·43
March	90·84	88·72	92·28	87·68	90·28	91·77	91·42	92·26	91·11	85·72	90·76	90·65

TABLE XIV

Serial No.	Variety	Commencement of ripeness	Month up to which ripeness is maintained	In cane at maximum maturity		Average weight per cane lb.
				Sucrose per cent	Fibre per cent	
1	Co 419	February	March	16·04	13·86	2·97
2	Co 413	January	March	14·6	16·66	2·37
3	POJ 2878	December	February	16·54	16·35	2·64
4	Pundia	February	March	14·438	11·61	2·95

The variety Co 419 is slightly less in sucrose content than POJ 2878 and is also comparatively less hard than POJ 2878. The varieties Co 419 and Co 413 were found to record very steady weight per cane during the three years' testing compared to the control varieties and an increased weight per cane over POJ 2878.

Relative yield performance with the control varieties.—The comparative value of these Co varieties from standpoint of cane, *gul* and commercial cane sugar taking POJ 2878 and Pundia as 100 is presented in Table XV.

TABLE XV

(*Average of three years 1935-37*)

Per acre	Co 419	Co 413	POJ 2878	Pundia
		Cane		
Tons	48·58	45·11	34·13	29·47
Percentage on POJ 2878	142·30	132·10	100·00	86·32
Percentage on Pundia	164·80	153·10	115·80	100·00
		Gul		
Tons	5·59	4·66	4·03	3·38
Percentage on POJ 2878	138·7	115·6	100·00	83·87
Percentage on Pundia	165·4	137·9	119·20	100·00
		C. C. Sugar		
Tons	6·59	5·63	4·92	3·56
Percentage on POJ 2878	134·00	114·40	100·00	74·03
Percentage on Pundia	185·10	158·10	138·20	100·00

Conclusions.—The varieties Co 419 and Co 413 are outstandingly superior to POJ 2878 and Pundia from standpoint of cane, *gul* and sugar. The varieties Co 413 and Co 419 have got very good root-system and erect habit of growth. Co 413 is very nearly a mid-late cane and Co 419 is mid-late to late in maturity. Co 413 produces *gul* of superior quality and Co 419 is the next best. Co 419 has almost the same sucrose-content in cane as POJ 2878.

EXPERIMENT III

Early varietal trials including sugarcane, sorghum hybrids, 1934-35 to 1936-37

When the cane selection work was commenced in 1933, it was observed that some of the selections showed maturity even at the tenth month ; hence these were separately grouped and tested as early varieties. In the same year, the sugarcane-sorghum hybrids which were reported to mature within six months were also received. So a combined trial consisting of the early varieties Co 407, Co 408, Co 411, Co 413 and HM 606 together with the six sugarcane-sorghum hybrids Co 351 to Co 357 (except Co 354) was undertaken. Replicated and randomised layout was adopted as in the final varietal test with a smaller plot-size and three feet distance between rows instead of four feet. The manurial dose was 150 lb. nitrogen as in the above experiments. The soil of this block where these tests were conducted had lower fertility trend as compared to the soil in which varieties described in experiments I and II were tested.

POJ 2878 was grown as a control variety throughout this period, and Co 360 during the latter two years only.

Year 1934-35.—In this year, varieties Co 407, Co 408, Co 411, Co 413 and HM 606 together with Co 351 to 357 (except Co 354) were under trial.

The yield performance of Co 413, Co 408, HM 606, Co 352, Co 355 and Co 356 are almost equal to or slightly better than POJ 2878. From maturity point of view Co 411 and Co 407 have shown indications of earliness. Sugarcane-sorghum hybrids begin to mature from tenth month onwards.

Year 1935-36.—As the variety Co 413 was found to be late it was transferred during this year in the final trial described in experiment II. HM 606 was discontinued as it was a lodging variety with low sucrose-content.

As in the previous year, none of the varieties are significantly better than POJ 2878 ; however the sugarcane-sorghum hybrids Co 352, Co 353 and Co 356 have yielded slightly higher than POJ 2878.

The varieties Co 407 and Co 411 show maturity from tenth month onwards (as in the previous year). Amongst the sugarcane-sorghum hybrids the earliest to mature are Co 351 and Co 352 ; the remaining varieties ripen between ten and eleven months.

Year 1936-37.—As a result of the data available for the last two years, only Co 352, Co 353 and Co 356 amongst sugarcane-sorghum hybrids were continued for trial, together with early varieties to which Co 421 was added.

The varieties Co 360, Co 421 and Co 408 have yielded significantly better than POJ 2878. Co 411 is almost significant over POJ 2878. Co 407 is equal in performance to POJ 2878.

The cane-sorghum hybrid Co 356 is significantly better than POJ 2878 and Co 352 and Co 353 have yielded as much as POJ 2878.

The cane varieties Co 360 and Co 421 show ripeness from tenth month onwards.

The cane-sorghum hybrids do not even show the start of maturity earlier than 8½ months ; definite trend towards maturity is seen only after 9½ or 10 months.

The three years' data of cane per acre are presented in Table XVI year by year.

TABLE XVI

Yield of millable canes in tons per acre
(Data for three seasons)

Yield												General mean	S. E. of variety mean	Whether general effect of treatment sig. by z-test	C. D. for significance
Co 407	Co 408	Co 411	Co 413	HM 606	Co 351	Co 352	Co 353	Co 355	Co 356	Co 357	POJ 2878				
							1934-35								
31·0	35·44	31·58	36·22	36·48	30·98	37·07	31·67	36·29	37·48	31·84	34·39	34·32	3·03	Not significant with POJ 2878 as control	8·92
							1935-36								
Co 407	Co 408	Co 411	Co 360		Co 351	Co 352	Co 353	Co 355	Co 356	Co 357	POJ 2878				
27·51	27·74	25·17	30·35		22·59	29·16	31·46	26·77	29·74	27·67	28·10	27·88	1·45	Not significant with POJ 2878 as control	4·29
							1936-37								
Co 407	Co 408	Co 411	Co 360	Co 421		Co 352	Co 353	Co 356			POJ 2878				
26·97	28·66	29·29	35·26	35·01		26·90	27·25	30·91			25·87	30·01	1·14	Significant	3·42

Conclusions:—1934-35—POJ 2878 sig.>all the varieties
1935-36—Co 353>Co 360>Co 356>Co 352>POJ 2878>Co 407, Co 408>others
1936-37—(1) Co 360, Co 421, Co 408, Co 356, Co 411 sig.>POJ 2878 (2) Co 356 sig.>Co 353=Co 352 (3) Co 360=Co 421 sig.>Co 356, Co 353, Co 352, Co 411, Co 407 (4) Co 408 sig.>Co 407, Co 411

Developmental records

Germination.—At three weeks only POJ 2878 is found to give early and high germination compared to the other varieties. At eight weeks, most of the varieties reach the level of germination as in POJ 2878 except Co 353, Co 356 and Co 360 (Table XVIII).

Borer attack.—The severity of borer attack was much less in 1936-37 than in 1935-36. Excepting Co 360, all the varieties have practically the same percentage of borer attack as POJ 2878.

Tillering.—Periodical changes in tillering at four different periods from germination till harvest for two years is averaged in Table XVII

TABLE XVII

Total shoot counts

(*Average of three replicates*)

(*Area of plot=0·75 gts.*)

Variety	At 8 weeks	Before earthing	After earthing	Percentage of success on before earthing-up count	At harvest	Percentage of success on before earthing-up	Remarks
Co 352	575	1971	1067	54·1	885	44·9	Buds planted 750 ; equivalent to 40,000 beds per acre
Co 353	412	1339	891	66·5	837	62·5	
Co. 356	430	1590	879	55·3	740	46·5	
Co 407	590	1801	881	48·9	761	42·3	
Co 408	514	1943	867	44·6	779	40·1	
Co 411	534	1885	880	46·7	689	36·5	
POJ 2878	568	1147	749	65·3	626	54·6	
Co 360	437	935	734	78·5	620	66·3	

The data in Table XVII, when reduced to the number of shoots obtained at different periods and millable canes at harvest for 100 planted buds (Table XVIII), clearly shows the high, medium and low tillering in different varieties ; the data regarding the percentage of germination and borer attack are also given in Table XVIII.

Habit.—The varieties Co 356, Co 360, Co 411 and POJ 2878 have almost erect habit of growth ; the varieties Co 352, Co 353, Co 407 and Co 408 have sub-erect habit and these also tend to lodge. With very vigorous growth the varieties Co 360 and Co 356 also tend to lodge.

TABLE XVIII

Percentage of germination, borer attack and ratio of number of shoots on 100 planted buds

Variety	At 8 weeks	Borrer attack per cent	Before earthing	After earthing	At harvest
Co 352	76·7	7·6	262·8	142·3	118·0
Co 353	55·0	5·7	178·5	118·8	111·6
Co 356	57·4	6·4	212·0	117·2	98·7
Co 407	78·7	5·8	240·1	117·5	101·5
Co 408	69·0	6·5	259·1	115·6	103·9
Co 411	71·2	8·0	251·3	117·3	91·87
POJ 2878	75·8	6·1	152·9	99·9	83·5
Co 360	58·2	9·5	124·7	97·9	82·7

From Table XVIII the varieties could be classified as in Table XIX.

TABLE XIX

Tillering	Varieties
High	Co 352, Co 353
Medium	Co 356, Co 407, Co 408
Low	POJ 2878, Co 360, Co 411

The percentage of flowering canes in the different varieties as recorded on 23 December 1935 was as in Table XX.

TABLE XX

Flowering data

Variety	Percentage of flowering
Co 352	78·1
Co 353	74·9
Co 356	61·1
Co 407	63·2
Co 408	72·2
Co 411	92·3
Co 360	78·6 Fluctuating
POJ 2878	91·7

March of ripeness.—In this trial, the chief consideration being earliness, it was watched from tenth month onwards in the case of Co selections and ninth month in the case of sugarcane-sorghum hybrids; brix and purity tests were taken monthly in the case of Co selections and at twenty days' interval in the case of sugarcane-sorghum hybrids ; these are presented in Tables XXI-XXIII.

TABLE XXI

Brix and purity, 1934-35

Variety	Brix (at No. of days from planting)			
	*270	300	330	
			Brix	Purity
Co 407	16·80	18·87	18·11	90·78
Co 408	14·51	16·63	20·61	90·76
Co 411	14·73	19·00	19·84	90·14
Co 413	15·91	17·97	19·11	90·57
HM 606	11·81	13·72	15·21	80·74
POJ 2878	..	18·01	20·73	92·21

TABLE XXI—*contd.*

Variety	Brix (at No. of days from planting)					
	*240	260	280	300	320	
					Brix	Purity
Co 351	14·69	16·11	17·17	18·10	19·98	86·36
Co 352	13·75	16·31	17·37	18·32	18·24	86·98
Co 353	13·13	15·18	15·57	17·82	17·44	86·76
Co 355	13·75	16·32	16·82	18·12	18·40	85·67
Co 356	12·52	14·10	15·47	17·12	17·16	81·0
Co 357	13·69	15·08	15·72	17·03	16·98	84·09
POJ 2878	13·79	15·43	17·23	18·01	20·47	89·45

*[As the polariscope was sent for repairs the readings in early stages could not be recorded.

Table XXII

Brix and purity, 1935-36

Variety	Brix (at No. of days from the date of planting)					
	270		300		330	
	Brix	Purity	Brix	Purity	Brix	Purity
Co 407 . .	16·78	82·73	19·52	86·50	22·25	89·39
Co 408 . .	15·11	81·27	17·80	86·52	20·37	89·69
Co 411 . .	16·53	80·34	19·70	88·45	20·60	80·08
POJ 2878 .	15·36	76·83	19·24	86·96	20·06	90·14
Co 360 .	17·23	85·23	18·72	88·51	20·65	90·24

Table XXII—*contd.*

Variety	Brix (at No. of days from the date of planting)									
	240		260		280		300		320	
	Brix	Purity	Brix	Purity	Brix	Purity	Brix	Purity	Brix	Purity
Co 351 . .	15·54	79·21	17·48	84·01	19·14	86·70	20·29	89·10	21·29	90·42
Co 352 . .	16·22	81·94	17·53	88·61	19·59	86·65	20·73	92·17	21·07	90·69
Co 353 . .	15·02	79·64	16·85	85·69	17·98	88·63	17·96	89·99	19·37	89·74
Co 355 . .	14·91	81·47	17·09	85·65	17·59	87·44	18·47	89·02	19·47	88·16
Co 356 . .	12·86	72·07	13·98	74·66	14·72	78·05	15·57	80·98	17·41	81·39
Co 357 . .	14·74	80·30	16·07	83·24	16·93	85·65	17·54	87·74	18·98	87·70
POJ 2878 . .	14·68	75·25	15·45	77·29	17·82	84·29	19·24	86·96	20·00	88·20
Co 360 . .	13·87	76·33	15·67	82·90	17·13	85·43	18·72	88·51	20·15	89·16

Table XXIII

Brix and purity, 1936-37

Variety	Brix (at days from planting)					
	270		300		330	
	Brix	Purity	Brix	Purity	Brix	Purity
Co 407 . .	17·33	79·77	21·43	88·86	21·99	88·20
Co 408 . .	15·88	79·60	17·08	85·69	18·99	86·56
Co 411 . .	19·42	86·68	20·78	90·90	20·88	89·82
Co 421 .	18·97	82·98	21·72	89·50	22·49	90·16
POJ 2878 .	16·72	78·27	19·58	86·12	20·10	87·36
Co 360 . .	17·29	82·77	19·52	89·35	21·33	90·67

TABLE XXIII—*contd.*

Variety	Brix (at days from planting)									
	240		260		280		300		320	
	Brix	Purity	Brix	Purity	Brix	Purity	Brix	Purity	Brix	Purity
Co 352	15·90	81·87	19·17	89·62	19·96	90·36	21·27	91·26	21·74	91·49
Co 353	14·48	79·69	16·84	84·01	18·18	88·33	19·85	89·71	20·78	91·24
Co 356	12·19	66·71	15·37	79·23	15·87	80·32	18·67	85·67	20·28	86·48
POJ 2878	10·82	59·53	15·82	77·49	17·62	80·87	19·58	86·12	21·21	88·90
Co 360	14·31	77·02	16·36	81·55	17·82	84·74	19·52	89·35	20·44	90·33

The period at which ripeness commences in different varieties, the data regarding the average weight per cane and sucrose and fibre-content in cane are summarised in Table XXIV.

TABLE XXIV

Variety	Period when ripeness commences (in months)	In cane at maximum maturity		Average weight per cane lb.
		Sucrose per cent	Fibre per cent	
Co 352	9¼ to 10	15·55	15·50	1·55
Co 353	9¼ to 10	13·94	16·79	1·69
Co 356	10 to 10½	13·52	18·67	2·05
Co 407	10	16·35	16·45	1·78
Co 408	11 to 11½	15·72	15·34	1·89
Co 411	10	15·29	13·81	1·94
Co 360	10 to 10½	16·84	14·04	2·54
POJ 2878 . . .	10 to 10½	16·63	14·42	2·14

The varieties Co 360 and Co 407 are almost equal in sucrose-content to POJ 2878, and Co 407 is comparatively more fibrous ; the sugarcane-sorghum hybrids are higher in fibre-content compared to the varieties Co 360 and POJ 2878.

Relative yield performance with control varieties

The comparative value of the Co varieties and sugarcane-sorghum hybrids from standpoint of tonnage, average of three years, taking POJ 2878 and Co 360 as 100 is presented in Table XXV.

TABLE XXV

Relative yield performance of varieties

Variety	Cane in tons per acre (average of three years	Comparative value of different varieties from standpoint of cane-taking	
		Co 360 as 100	POJ 2878 as 100
Co 352	31·04	90·44	105·4
Co 353	30·13	87·48	102·0
Co 356	32·71	95·28	111·1
Co 407	28·49	83·01	96·77
Co 408	31·95	93·09	108·5
Co 411	28·68	83·56	97·4
Co 360	34·36	100·00	116·6
POJ 2878	29·45	85·78	100·0

Conclusions.—In this shallower type of soil, the varieties Co 360, Co 356, Co 408, Co 352 and Co 353 have yielded as much as POJ 2878 but slightly less than Co 360. The variety Co 360 has as much sucrose per cent in cane as POJ 2878 and the varieties Co 407, Co 408 and Co 352 are the next best. The cane-sorghum hybrids do not show maturity earlier than 9½ months and the control varieties Co 360 and POJ 2878 show trend towards maturity from tenth month onwards. The cane-sorghum hybrids are comparatively more fibrous than the control varieties.

EXPERIMENT IV

October-planting trials, 1934-35 to 1936-37

Investigations in the performance of Coimbatore selections described previously have definitely shown that under Padegaon conditions all the promising varieties start flowering from October to December, and with this the growth closes. This is found to result in low yields specially in the early-flowering varieties. It was, therefore, proposed to see what advantage could be gained by planting these varieties in October as it was considered that by this early planting the crop would get additional two to three months for its growth. With this view the trials were commenced with the promising selections from October 1934, the method being exactly similar as in the trials previously described but with only a smaller plot size. The manurial dose was increased to 225 lb. nitrogen from the usual 150 lb. for January planting.

Co 407 Co 408 Co 413 Co 419 Co 290 POJ 2878 EK 28

October planting : age of crop 14½ months

These trials were conducted for three years. As some of the varieties were discontinued from the second year, the results are represented year by year. The varieties POJ 2878 and EK 28 were grown as control during this three-year period.

Year 1934-35.—During this period, thirteen varieties, together with two control varieties were under trial.

Co 413 and Co 419 have yielded significantly better than the control varieties. Co 290 and Co 407 have equalled POJ 2878. Co 360, Co 364, Co 400, Co 408, Co. 410, Co 411 and Co 414 are significantly better than EK 28.

Year 1935-36 and 1936-37.—During these two years the varieties Co 364, Co 400, Co 404, Co 410, Co 411 and Co 412 were omitted and the remaining were continued.

In 1935-36, Co 419 and Co 413 are significant over POJ 2878. All the remaining varieties are significantly better than EK 28.

In 1936-37, the varieties Co 419, Co 290, Co 413, Co 408, Co 414 are significantly better than POJ 2878 ; the varieties Co 360 and Co 407 show better than POJ 2878.

The three years' data of cane and commercial cane sugar per acre are presented in Table XXVI year by year.

Some of these varieties are illustrated in Plate XXXII.

Developmental records

Germination.—Unlike the January planting, very high germination is secured at three weeks in this planting. Maximum germination occurs at six weeks. The varieties Co 419, Co 413 and Co 407 have come out the best. (Table XXVIII).

Borer attack.—The incidence of borer attack is the least in this planting compared to the January planting.

Periodical changes in tillering.—Periodical changes in tillering (average of two years) are presented in Table XXVII.

The data in Table XXVII, when reduced to number of shoots obtained at different periods and millable canes at harvest for 100 planted buds (Table XXVIII), clearly show the high, medium and low tillering in different varieties ; data regarding percentage of germination and borer attack are also given in Table XXVIII.

On the basis of the data in Table XXVIII the varieties can be classified as shown in Table XXIX.

It is interesting to observe, that in this planting the ratio of millable canes at harvest is uniformly higher in all the varieties compared to January planting (Tables IV and XI).

Habit.—The varieties Co 290, Co 360, Co 413, Co 419, E K 28 and POJ 2878 have almost erect habit of growth ; the varieties Co 407, Co 408 and Co 414 have sub-erect to slanting habit. The varieties Co 419 and Co 360 tend to lodge in varying degrees at harvest time.

The percentage of flowering canes in different varieties as recorded on 21 November 1937 was as shown in Table XXX.

March of ripeness.—The year-by-year data for brix and purity is presented in Table XXXI.

TABLE XXVI

Yields of millable canes and commercial cane sugar in tons per acre
(Data for three years)

	Co 290	Co 360	Co 407	Co 408	Co 413	Co 414	Co 419	POJ 2878	E K 28	Co 364	Co 400	Co 404	Co 410	Co 411	Co 412	General mean	S. E. of treatment mean	Significance by z-test $P=0\cdot05$	Critical difference for significance
1934-35																			
Cane	46·91	42·92	45·47	42·70	53·76	41·27	62·59	45·11	31·94	44·04	45·04	41·65	41·72	43·17	38·08	44·42	2·89	Significant	7·97
C. C. S.	5·84	6·47	6·18	5·74	7·17	5·93	7·09	6·42	4·36	5·50	4·29	5·10	5·60	5·63	4·76	Not calculated statistically			
1935-36																			
Cane	50·44	46·93	50·66	50·48	54·64	52·02	68·57	47·69	[illegible]	...	...	...	...	...	...	50·8	2·47	Significant	7·22
C. C. S.	6·14	5·46	6·83	6·89	6·93	7·29	8·55	6·90	4·89	...	...	...	...	...	...	Not calculated statistically			
1936-37																			
Cane	2·05 6	47·41	46·41	54·16	58·26	53·88	70·04	39·83	30·21	...	...	...	...	...	...	51·37	2·90	Significant	8·47
C. C. S.	9·31	6·43	6·35	7·06	7·93	7·63	9·72	5·65	4·21	...	...	...	...	...	...	Not calculated statistically			

Conclusions :—1934-35.—Co 419, Co 413 sig. > POJ 2878
1935-36.—Co 419 sig. < POJ 2878 ; Co 413 almost sig. > POJ 2878 ; Co 413, Co 414, Co 407 = Co 408 = Co 290 > POJ 2878 = Co 360 sig. > EK 28
1936-37.—Co 419, Co 290, Co 413, Co 408, Co 414 sig. > POJ 2878 ; POJ 2878 sig. > EK 28

TABLE XXVII

Total shoot counts

(Average of four replicates)

(Area of plot 0·33 gts.)

Variety	At 6 weeks	Before earthing	After earthing	Percentage of success on before earthing-up count	At harvest	Percentage of success on before earthing-up count	
Co 419	199	577	429	74·3	393	68·1	Buds planted=250 (equivalent to 30,000 buds per acre)
Co 413	200	814	529	65·0	402	49·4	
Co 290	179	714	516	72·3	457	64·0	
Co 407	192	565	438	77·5	410	72·6	
Co 408	170	502	397	79·1	368	73·3	
Co 360	171	387	364	94·1	349	90·2	
Co 414	183	539	380	70·5	316	58·6	
POJ 2878	179	498	352	70·7	317	63·7	
EK 28	164	314	256	81·5	230	73·2	

TABLE XXVIII

Percentage of germination, borer attack and ratio of number of shoots on 100 planted buds

Variety	At 6 weeks	Borer attack per cent	Before earthing	After earthing	At harvest
Co 419	79·9	1·1	230·8	171·6	157·2
Co 413	80·1	1·0	325·6	211·6	160·8
Co 290	71·6	0·7	285·6	206·4	182·8
Co 407	77·0	1·0	226·0	175·2	164·0
Co 408	67·9	1·6	200·8	158·8	147·2
Co 360	68·1	2·0	154·8	145·6	139·6
Co 414	73·4	1·8	215·6	152·0	126·4
POJ 2878	71·7	0·8	199·2	140·8	126·8
E K 28	65·7	2·0	125·6	102·4	92·0

TABLE XXIX

Tillering	Varieties
High	Co 290
Medium	Co 413, Co 419, Co 407, Co 408
Low	Co 360, Co 414, POJ 2878
Very low	EK 28

TABLE XXX

Flowering data (October planting)

Variety	Percentage of flowering
Co 290 . .	72·7
Co 360 . .	10·6
Co 407 . .	64·9
Co 408 . .	50·3
Co 413 . .	56·4
Co 414 . .	41·0
Co 419 . .	76·7
POJ 2878 .	80·8
EK 28 . .	20·9

On account of the long interval over which the crop is standing, and also practically the same time of flowering, its tendency to being early, mid-late or late is not clearly visible in the different varieties. Yet the varieties, Co 407, Co 408, Co 360, POJ 2878 could be started for crushing from November and the remaining in December.

The average weight per cane and percentage of fibre and sucrose in cane in the different varieties is given in Table XXXII.

The varieties Co 414 and POJ 2878 show same sucrose-content and the remaining varieties, except Co 360, follow next. Most of the va ieties were found to record very steady weight per cane from year to year.

Relative yield performance.—The comparative value of the Co varieties from standpoint of cane and commercial cane sugar, with POJ 2878 and EK 28 as 100, average of three years, is presented in Table XXXIII.

Conclusions.—The variety Co 419 has outyielded all the varieties including the controls. The varieties Co 413, Co 290, Co 414 and Co 408 have given slightly higher tonnage than POJ 2878 but from sugar point of view these are almost equ valents or slightly better than POJ 2878. There is not much differentiation in the ripening of the different varieties owing to the pre-seasonal time of planting and most of the varieties show ripenes at $13\frac{1}{2}$ to $14\frac{1}{2}$ months' age of the crop. It is interesting to observe that most of the varieties except Co 419, Co 413 and Co 290 show practically the same sugar recovery as

TABLE XXXI

Brix and purity data

Serial No.	Variety	October			November			December			January			February			March		
		1935	1936	1937	1935	1936	1937	1935	1936	1937	1935	1936	1937	1935	1936	1937	1935	1936	1937
								Brix											
1	Co 419 .	14·13	17·46	17·9	17·74	19·99	19·51	21·12	20·40	21·77	...	22·63	22·67	...	20·60	13·5	...	16·65	21·30
2	Co 413 .	16·01	17·84	18·37	18·79	20·29	20·09	21·07	19·91	20·31	...	21·78	22·53	...	21·35	22·68	...	18·73	20·62
3	Co 290 .	16·28	18·84	18·44	18·82	20·06	19·72	20·15	20·94	21·42	...	21·50	21·02	...	21·04	21·60	...	19·80	18·88
4	Co 407 .	15·16	18·96	18·88	19·14	21·62	21·79	21·84	22·85	23·22	...	23·16	21·01	...	22·12	22·47	...	20·03	18·58
5	Co 408 .	16·78	18·38	17·62	18·56	21·29	19·79	21·02	22·09	21·03	...	22·43	22·31	...	22·22	22·83	...	19·20	21·43
6	Co 360 .	15·50	20·49	19·82	15·90	21·52	20·11	21·22	19·67	20·61	...	22·13	22·20	...	21·29	21·22	...	18·86	19·28
7	Co 414 .	17·06	19·99	20·04	19·44	21·85	20·64	21·61	22·55	22·16	...	22·05	22·49	...	18·94	20·31	...	14·76	15·82
8	POJ 2878	16·42	20·22	20·55	19·28	23·39	22·61	21·79	22·56	23·09	...	23·46	23·73	...	22·22	22·56	...	19·12	19·02
9	EK 28 .	17·08	18·95	20·94	18·47	20·17	21·44	20·90	20·86	21·43	...	21·63	22·96	...	21·88	24·8	...	19·23	21·73
								Purity											
1	Co 419 .	75·60	83·81	83·41	83·99	89·78	88·10	89·32	87·26	90·07	...	89·74	89·84	...	90·57	91·45	...	86·24	90·99
2	Co 413 .	82·64	86·76	88·90	86·48	90·59	91·37	91·85	90·82	91·16	...	90·99	91·47	...	90·55	92·47	...	88·47	91·77
3	Co 290 .	80·97	87·84	85·43	85·47	89·30	86·92	87·70	86·64	88·90	...	89·50	88·45	...	88·84	88·45	...	88·26	86·20
4	Co 407 .	75·34	85·96	85·88	82·94	90·40	89·62	90·59	89·66	90·42	...	89·0	88·24	...	90·44	89·13	...	87·38	86·86
5	Co 408 .	83·83	88·74	88·76	86·80	91·94	90·65	92·41	90·01	90·67	...	90·67	91·70	...	91·22	90·72	...	87·82	90·80
6	Co 360 .	79·49	89·95	90·67	80·50	91·43	90·31	92·37	86·90	91·70	...	90·67	84·35	...	88·47	85·02	...	83·56	78·16
7	Co 414 .	82·30	87·36	87·98	36·38	90·84	91·03	92·30	88·92	90·40	...	90·44	89·48	...	89·73	88·14	...	81·04	82·45
8	POJ 2878	78·75	88·67	89·33	86·88	91·37	91·39	92·26	91·37	91·94	...	92·47	92·43	...	91·91	92·47	...	89·13	87·44
9	EK 28 .	83·62	86·44	90·61	84·80	89·50	91·28	92·06	90·82	91·52	...	90·55	91·70	...	90·86	92·45	...	85·96	90·93

POJ 2878. EK 28 has proved a complete failure in this trial. Unlike other plantings most of the varieties in this planting give higher number of millable canes at harvest and the intensity of borer attack is the least.

TABLE XXXII

Chemical composition and average weight per cane

	Co 419	Co 413	Co 296	Co 407	Co 408	Co 360	Co 414	POJ 2878	EK 28
Average weight per cane (lb.)	3·28	2·62	2·29	2·21	2·65	2·53	3·13	2·57	2·67
Fibre per cent in cane .	12·39	13·87	14·18	18·41	15·24	13·28	13·03	15·87	12·51
Sucrose per cent in cane .	15·55	15·28	15·19	15·46	15·50	14·18	16·55	16·48	15·79

TABLE XXXIII

Cane and commercial cane sugar in tons per acre

(*Three years' average*)

	Co 419	Co 413	Co 290	Co 407	Co 408	Co 360	Co 414	POJ 2878	EK 28
Cane tons per acre	67·07	55·55	53·13	47·51	49·11	45·75	49·06	44·21	32·65
Percentage on POJ 2878	151·7	151·7	120·1	107·5	111·1	103·5	111·0	100·0	73·86
Percentage on EK 28	205·4	170·1	162·8	145·5	150·4	140·2	150·3	135·4	100·0
C. C. S. tons per acre	8·45	7·34	7·10	6·45	6·56	6·02	6·95	6·32	4·49
Percentage on POJ 2878	133·8	116·1	112·4	102·1	103·8	95·26	110·0	100·0	71·04
Percentage on EK 28	188·2	163·5	158·1	143·6	146·1	134·1	154·8	140·8	100·0

SUMMARY AND CONCLUSION

Cane selections together with sugarcane-sorghum hybrids numbering in all seventy-nine, from Coimbatore, Hebbal-Mysore and Manjri were under trial, from which promising selections were grouped and tried for three years as January-planted crop. They were also under trial as October-planted crop. All the trials were on replicated system and the data analysed as per Fisherian method. The results have been expressed in cane-weight, *gul* and commercial cane sugar together with the maturity period of each variety and its general behaviour as regards habit, incidence of pests, etc.

(1) As January-planted crop, the varieties Co 419, Co 413 and HM 320 have proved their superiority over the control varieties POJ 2878, EK 28 and Pundia. When both the groups are considered together Co 290 and Co 360 have not only come up to the level of POJ 2878 but are superior to EK 28 and Pundia in cane-weight, *gul* and commercial cane sugar. As regards maturity, Co 419 ripened within $12\frac{3}{4}$ months, HM 320 within 13 to $13\frac{1}{2}$ months. From the point of keeping quality it is observed that Co 419, Co 413, Co 360 and Co 290 could keep up juice quality till March, whilst

HM 320, a late-maturing cane, keeps even longer. In the developmental behaviour of the crop the important points are germination, tillering, lodging, ease of trashing, and good root-system. From all these aspects. Co 419, Co 413 and Co 290 are the best. Co 360 has a peculiar root-system, which is conducive to rapid growth but being defective induces lodging. It is not also self-stripping, and is, therefore, susceptible to mealy bugs. However, it has shown a good performance as late-planted crop even though it is a flowering variety. HM 320 has also a lodging tendency and is further poor in sucrose as Pundia. Thus, Co 419, Co 413, Co 290 and even Co 360 can be good factory canes and HM 320 a cultivator's cane.

(2) As regards early cane selections and sugarcane-sorghum hybrids, planted in January, Co 407 and Co 411 have proved to be eleven months' cane whilst sugarcane-sorghum hybrids have not shown start in maturity before 9½ months which has falsified the expectation of its reaching maturity in six months. Although the yield is not the main factor for drawing conclusion in the case of these varieties no marked superiority is observable of early varieties as well as sugarcane-sorghum hybrids over POJ 2878.

(3) As regards October-planting, varieties Co 419, Co 413, Co 290, Co 407, Co 408 and Co 414 have shown their superiority over the control varieties POJ 2878 and EK 28 ; Co 360 is a mediocre cane in cane-weight and also in commercial cane sugar. It would further be seen that the benefit of additional three months for flowering varieties has resulted in highly increased number of canes at harvest which fully go to increase the yield significantly in the end.

Acknowledgements

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EMBRYO OF THE INDIAN MANGOES (*MANGIFERA INDICA* LINN.)

BY

P. K. SEN

AND

P. C. MALLIK

Fruit Research Station, Sabour, Bihar

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(With Plates XXXIII and XXXIV and three text-figures)

IN the studies on mango at Sabour, the embryo has received attention from two aspects. Firstly, it is known that large amount of carbohydrates are utilised in developing the fruits but the embryos in the seeds require more nitrogen than carbohydrate for their growth and development, whereas fruit-bud formation is believed to be dependant on a high carbohydrate-nitrogen ratio. A knowledge of the relative times of growth and development of the fruit, seed and embryo as also that of the fruit-bud differentiation in mango would, therefore, be of interest in connection with the problem of alternate bearing in this fruit. Secondly, it seems important that it is necessary to have a knowledge of the behaviour of the embryo because of the possibilities of improving the present varieties by hybridization, and also if it may be possible to use the apogamically produced seedlings in the polyembryonic strains as clonal root-stocks.

THE RELATIVE TIMES OF GROWTH AND DEVELOPMENT OF THE FRUIT, SEED AND EMBRYO

As far as the writers are aware, no study on this aspect of the mango has yet been made, although it has received attention in a number of other fruits ; thus Connors [1919], Blake [1925], Lilleland [1931; 1934], Tukey [1933 ; 1934] and others working on peach, plum, apricot and cherry have shown that development of stone-fruit passes through three well-marked stages : (1) Rapid growth after fertilization due mainly to increase in size of stone. The nucellas and integuments grow rapidly to full size, but the embryo does not start active growth until near the end of this period. (2) A period during which the growth of fruit is retarded but the stone hardens and the embryo rapidly reaches full development. (3) Renewed rapid development of the fruit to maturity. Sen [1937] found a similar phenomenon in apple. The work described below was taken up with a view to gathering the information in mango.

A sample number of fruits was collected every week from the time of fruit set-up to the time of fruit-maturity in the Bombai, Langra and Fazli mangoes and the volume, and maximum length, breadth and thickness of the fruit, seed and embryo, and only the lengths of the radicle and plumule separately, were determined. During the first two to three weeks when the fruits

were yet within one cm. in length, a sample consisted of 50-100 fruits, then until they were within about 2·5 cm., a sample consisted of twenty-five fruits, thereafter ten fruits were collected per week, from three comparable trees (sixteen year old in 1938) under each variety.

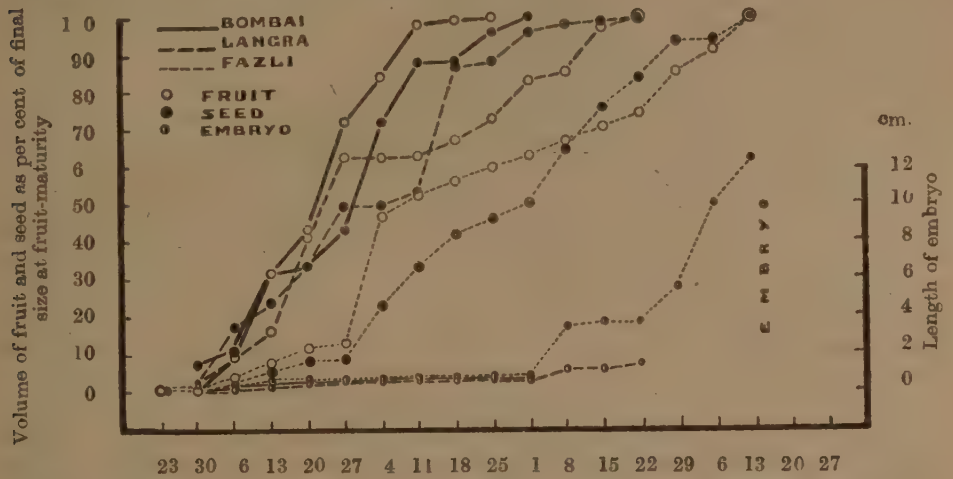

FIG. 1. Increases in volume of the fruit and seed expressed as percentage of the final size, at fruit-maturity and that in length of th radicle and plumule (marked as embryo) in 1938

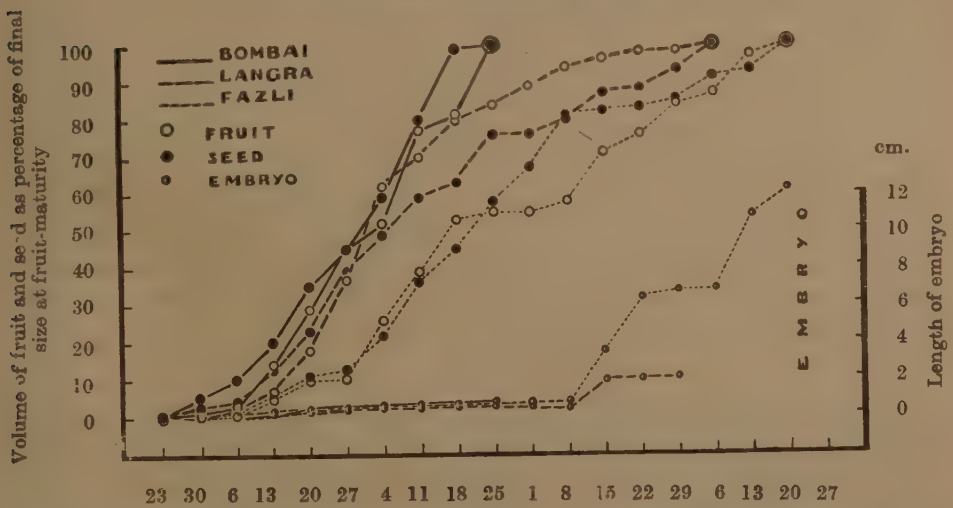

FIG. 2. Increases in volume of the fruit and seed expressed as percentage of the final size, at fruit-maturity and that in length of the radicle and plumule (marked as embryo) in 1939

The study was first made in 1938 and then repeated in 1939. The increases in volume of the fruit and seed, expressed as percentage of the final size, at fruit-maturity, and that in length of the radicle and plumule, in the three varieties, are graphically shown in Figs. 1 and 2 ; and only the relevant data are given in the appendix (Tables A and B).

The Bombai is an early variety ripening towards the end of May or beginning of June ; Langra, a mid-season variety ripening towards the end of June : and Fazli, a late variety ripening after the middle of July.

As will appear from Figs. 1 and 2, unlike the temperate fruits mentioned above, fruit and seed in the mango develop concurrently. The earlier the fruit ripens the more rapid is its rate of development. From the appendix (Tables A and B) it will be seen that the cotyledons in the mango also grow along with the seed, the rate of growth of the radicle and plumule, however, remains very s'ow until the beginning of June irrespective of the varieties and their times of fruit-maturity. In the case of Bombai where the fruit had reached full maturity by the end of May, the radicle and plumule showed little change in the rate of growth ; in the other two cases, however, the radicle and plumule showed a sudden rise in their rate of growth after the first week of June. Although the fruits of Langra and Fazli reached maturity at different times, their embryos showed this sudden increase at the same time, in both the years. After this sudden rise the rate of increase in both the varieties showed a flattening out again. The Langra variety maintained this retarded rate of growth till its fruit matured, but in the case of Fazli there was another abrupt rise towards the end of June in 1938, and after the first week in July in 1939 when in there respective years the Langra fruit had already ripened. This renewed rapid rate of increase continued till fruit-maturity, resulting in a phenomenon like vivipary, the plumules and radicles quite often reaching in some cases a length of 20 to 25 cm. An observation of this phenomenon in a ripe fruit of the Fazli mango was previously recorded by Nandi [1934].

Whether or not the sudden increases in the rate of gro th of the plumule and radicle observed in the cases of Langra and Fazli are due to seasonal influence, in some way related to the nutritional conditions of the tree, the writers have no sufficient data at the present moment to come to any conclusion. The one characteristic of the mango that its seed cannot be stored, at any rate, under the ordinary conditions, and that for successful germination, the stone should be sown soon after it is removed from the ripe fruit, should also be borne in mind in this connection. The suggestion put forward by Nandi [1934] that this phenomenon in Fazli might be due to unfavourable condition of the soil seems rather remote as it appears to be a normal feature of this variety, and as the varieties like Bombai and Langra grown on the same soils do not show this phenomenon.

Behaviour of the embryo

As to this second question, points of fundamental interest have arisen since it has been found that although pollination and fertilization is necessary for the development of the fruit, the zygote in mango does not always produce an embryo. It may degenerate and take no part at all in the production of any embryo in the seed. On the other hand adventive embryos of nucellar origin may arise.

The behaviour of the embryo in mango fruit first attracted attention because of the occurrence, in many cases, of more than one sprout from its seeds. According to Arndt [1935] Schacht recorded the presence of polyembryony in mango in 1859 ; Strasburger [1878] and Cook [1907] concluded that

the extra embryos were of nucellar origin, but the latt r failed to ascertain whether or not the ' strong ' embryo came from the fertilised megagamete. He noted as many as eight embryos arising from a single seed. Mendiola [1926] reported that ten or even thirty seedlings may grow from a single seed (Carabao or Pico variety).

Working on polyembryonic varieties, Belling [1908] in the Florida No. 11 mango and Juliano [1934] in the Strawberry mango have found that in these two cases the zygote totally fails to develop and all the embryos in a seed are nucellar in origin. Juliano and Cuevas [1932] and Juliano [1937], in the Pico and Carabao mangoes respectively, have shown that the zygote usually persists and forms a sexual embryo, but it may degenerate and take no active part in the production of any embryo in the seed. The adventive embryos in the seed are nucellar in origin. Juliano [1937] also concludes that in the cases of polyembryonic seeds where both sexual and asexual embryos are produced it has not been possible to ascertain, after the seedlings have sprouted, which of them came from the fertilised megagamete ; further, where only one sprout arises from a seed on germination, this seedling may have been produced either asexually or sexually.

Juliano opines that the Pico and Carabao mangoes are probably on their way to sterilization and degeneration in their zygotes so that in course of time they will also produce apogamic embryos only, and progenies true to type may be grown by seedage, as is the case now in Florida No. 11 and Strawberry mangoes.

The use of such mangoes as develop apogamic embryos only should, therefore, provide a sure method of supplying root-stocks that will produce uniform trees. On the other hand the zygote degeneration in mango is a serious handicap in hybridization work, as the varieties showing this phenomenon cannot be used as a female parent.

Although by far the largest number of our Indian mangoes are known to be mono-embryonic, i.e. only one seedling arises from one seed, polyembryonic varieties are not unknown. In fact the Strawberry mango on which Juliano has worked is described as an Indian variety. Several varieties of polyembryonic mangoes have been found in the Malabar Coast and the Kodur Fruit Research Station, Madras, has taken up their collection.

Incidentally, a point of fundamental interest noted by Juliano [1937] is that many of the mono-embryonic Indian mangoes when grown in the Philippines and Florida appear to develop polyembryony at least in a greater proportion, if not all, of their seeds when grown there. As to how this comes about, he doubts if it is due to natural cross-pollinations between the polyembryonic mangoes that are the natives of the locality, and the imported Indian varieties, as in that case, he thinks, all the Indian mangoes now growing in those islands should have shown polyembryony. He suggests that if it is a case of reversion due to the influence of environment, and if the progenies of the varieties which show such a phenomenon revert to mono-embryony when planted back in their own home, it may settle once and for all which character, poly or mono-embryony is the more primitive, and this may indicate the possible origin of all the present mangoes.

There again occurs another phenomenon, namely that many of our Indian mangoes, though in very small numbers, give rise to multiple shoots, but only

one tap-root in germination. These shoots arise from the hypocotyl. Arndt [1935] has described this phenomenon in mango in the West Indies. He is inclined to think that the multiple shoots which arise from the seeds may originate through polyembryony, the development of adventitious buds on the seedlings before or during germination, or a combination of the two types.

At our research station at Sabour, Bihar, we have almost every year seen many of the local varieties showing this phenomenon of multiple shoots in germinating seeds. The results of a record taken in 1939 are shown in Table I. In the case of Fazli where the embryo in the seed of a ripe fruit shows fairly advanced growth, instances of multiple plumules are quite commonly seen. A photograph of such a Fazli seed and, in contrast, a seed of an Indian polyembryonic mango, namely, Goa (Kasargod) is shown in Plate XXXIII, fig 1. Drawings of the same Fazli seed are shown in Fig. 3 so as to enable a clear examination of the orientation of the multiple shoots. From the two very distinct cotyledons, one single root and the axillary orientation of the extra shoots it would suggest that the present case is one of adventitious budding. Here the main plumule has actually been suppressed in the centre and some of the axillary ones have outgrown it. Plate XXXIII, fig. 2 (*a* and *b*) show photographs of two germinated seeds of Langra and Bombai respectively, producing multiple shoots. In these cases also, the extra shoots appear to have arisen from the axils of the cotyledons. Plate XXXIII, fig. 2 (*c*) shows a germinated seed of an Indian polyembryonic mango, namely Kurakkan producing three distinct seedlings, one of them further shows a side shoot arising from its hypocotyl.

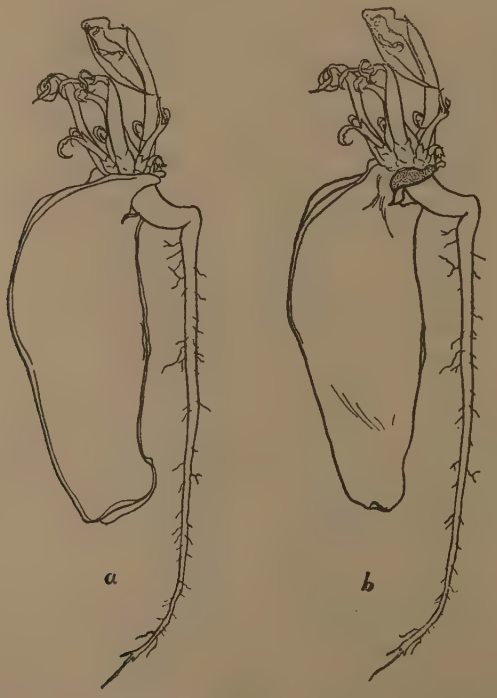

FIG. 3. Drawings of the Fazli seed photographed in Plate XXXIII, fig. 1, (*a*) with both the cotyledons intact, (*b*) after one of the cotyledons has been removed; showing extra shoots arising at the axils of the cotyledons

FIG. 1. (*a*) A Fazli seed showing multiple shoots but a single tap-root, (*b*) a polyembryonic seed of the Goa (Kasargod) mango showing three germinating embryos

FIG. 2. Germinated seeds : (*a*) Langra, (*b*) Bombai showing multiple shoots, (*c*) a polyembryonic seed (var. Kurakkan) showing three seedlings. The tips of the roots were unfortunately torn in excavation

A germinating polyembryonic seed (var. colour) showing the entire seed in two views and the five embryos 1-5 after separation

TABLE I

Number of shoots arising on germination in three varieties of mango

Seeds from		Number of seeds sown	Number germinated	Number of seeds producing			
				1 shoot	2 shoots	3 shoots	More than 3 shoots
Bombai	Seedling tree	280	208	205	2	1	..
	Grafted tree	280	217	210	3	3	1
Langra	Seedling tree	280	148	136	9	3	..
	Grafted tree	280	207	202	5	..	..
Fazli	Seedling tree	150	36	35	..	1	..
	Grafted tree	150	21	15	4	2	..

From the results shown in Table I, it would appear that the seeds collected from fruits of seedling trees and from grafted trees make little difference in germination ; but among the three varieties Fazli is a very poor germinater. Whether or not this indicates the occurrence of zygote degeneration or embryo abortion in this variety, has not been investigated, but cases of deformity of the embryo have been noticed in large numbers so that while in the varieties such as Bombai and Langra the cotyledons practically fill the cavity of the stone in this variety quite often, insignificant cotyledons with undeveloped radicle and plumule are found to occupy only one corner of the cavity.

In view of the above a knowldge of the behaviour of our polyembryonic as well as the important mono-embryonic varieties of mango seems to be important. In the case of the polyembryonic varieties no doubt it would appear difficult to distinguish the sexually produced seedling from the asexual ones, or the seeds possessing only asexually produced embryos from those which have both the sexual and asexual embryos ; but if it is possible to discover varieties like Florida No. 11 or Strawberry mango that produce all the embryos asexually, we shall be in a position to use them quite easily as root-stocks ensuring uniform trees.

As regards the mono-embryonic varieties, most of our economic mangoes belong to this group. Whether or not these varieties can be improved by hybridization in respect of quality and bearing habit* is yet to be known. For such attempts, a knowledge of the behaviour of their zygotes after fertilization will be of great help. Unfortunately, however, little work on this important aspect of the Indian mangoes has yet been done ; the only report known to the writers is a note on some preliminary observations made by Maheswari [1934].

* Most of the best quality of Indian mangoes are alternate bearers.

With the above in mind, samples of seeds of five varieties of our West Coast polyembryonic mangoes were collected through the courtesy of Mr K. C. Naik, Superintendent of the Kodur Fruit Research Station, Madras, and a preliminary morphological examination, including a germination test, of these was carried out during the last summer. The samples included seventy-five seeds of each of the four varieties, namely Olour, Goa, Goa (Kasargod) and Mylepelian and 500 seeds of Kurakkan, variety. The seeds were gathered, transported to Bihar from Madras and sown within a week in April-May 1939. The first four varieties were sown in seed-beds, and the last in pots at the rate of one seed per pot. After one week of sowing, when the seed had not yet germinated twenty-five seeds of each variety were unearthed for examination. Table II gives the number of embryos occurring in them. All these varieties showed more than one embryo in an overwhelming majority of cases; in each of the varieties, however, a few cases showing a single embryo, without any trace of polyembryony, were found. Among the 125 seeds examined in the five varieties, the highest number of embryos in a single seed was six, observed only in one case in the Kurakkan variety.

TABLE II

Polyembryony in mango

Variety	Number of stones examined	Number of stones with the following number of embryos					
		1	2	3	4	5	6
Kurakkan	25	5	11	6	2	0	1
Goa (Kasargod)	25	1	8	9	5	2	0
Olour	25	5	6	4	9	1	0
Mylepelian	25	4	8	8	4	1	0
Goa	25	6	15	0	0	0	0*

* Four rotted, no trace inside the stone

Plate XXXIV presents drawings of a germinating seed of the Olour variety. It shows the entire seed in two views and the five embryos after separation. As is found here, all the polyembryonic seeds examined have shown one 'strong' embryo having two cotyledons almost as big as a normal pair of cotyledons in a mono-embryonic seed. In the case of others, the size of the cotyledons varies according to the position in which it lies in the seed so as to accommodate all the cotyledons of all the embryos within the stone. Embryos 1 to 5 represent this feature.

Table III shows the results of germination in the five polyembryonic varieties. It appears that a considerable number of seeds in all the varieties failed to germinate successfully, also a good many of them finally produced only one seedling.

TABLE III

Number of seedlings arising on germination in five varieties of polyembryonic mango

Seeds from	Number of seeds sown	Number germinated	Number of seeds producing			
			1 seedling	2 seedlings	3 seedlings	More than 3 seedlings
Goa	50	8	5	2	1	..
Mylepelian . .	50	26	15	1	1	..
Olour	50	11	11	..	..	..
Goa (Kasargod) . .	50	23	16	5	2	..
Kurakkan . . .	410	150	30	45	41	34

No study of the developmental morphology of the embryos in either the polyembryonic or the mono-embryonic varieties have yet been made. The observations so far made have been recorded here in the hope that these will be of sufficient interest to botanical workers in India so as to attract their attention to the problems of the mango.

SUMMARY

Observations on the relative times of growth and development of the fruit, seed and embryo in three varieties of mango, namely Bombai, Langra and Fazli, the occurrence of multiple shoots in germinated seeds of the same varieties, and polyembryony in five other varieties of Indian mangoes, namely Olour, Kurakkan, Goa (Kasargod), Mylepelian and Goa are herein reported.

Unlike in apple and in some temperate stone-fruits where the fruits develop in three well-marked stages (*i*) seed and fruit growth, (*ii*) embryo growth and (*iii*) final development of the fruit to maturity, the fruit, seed and the cotyledons of the embryo in mango grow concurrently.

Of the three first-named varieties, Bombai is an early ripener, maturing by the end of May ; Langra, a mid-season variety, maturing towards the end of June ; and Fazli, a late variety, ripening after the middle of July. The earlier the fruit is due to ripen, the more rapid is its rate of growth.

The radicle and plumule grow at a very slow rate till the end of May so that in the case of Bombai it shows no change in the rate at all; in the other two varieties, however, there is an abrupt rise in the rate of growth of the radicle and plumule after the first week of July. The two varieties show this change irrespective of their time of fruit-maturity. After some time the rate flattens out again so that the Langra mango shows no other change in this respect till its fruit matures, but in the case of Fazli the radicle and the plumule

how another abrupt rise in the rate of their growth after the first week of July. This rapid rate of growth results into a phenomenon like vivipary. The radicle and plumule sprout out of the stone and quite often attain a length of 20-25 cm.

In all the three varieties, i.e. Bombai, Langra and Fazli cases of multiple shoots and only one tap-root on germination of the seeds are found to occur. In the case of Fazli, seeds with multiple shoots are sometimes found in the ripe fruits. The extra shoots appear to arise adventitiously from the axils of the cotyledons.

All the polyembryonic varieties were found to have a few mono-embryonic seeds. The polyembryonic seeds always have one strong embryo and the others vary in vigour according to their positions in the seed. It appears probable that a considerable number of the polyembryonic seeds fail to successfully germinate more than one or two seedlings.

The necessity for an investigation of the behaviour of the zygote after fertilization in both the mono and polyembryonic varieties has been stressed because of the possibilities of improving them by hybridization and using the apogamically produced seedlings in the polyembryonic strains as clonal stocks.

Thanks are due to the Imperial Council of Agricultural Research, India for maintaining the Fruit Research Scheme under which it has been possible to make this study. Thanks are also due to Mr A. C. Sinha, B. Sc. Ag. for assistance in measurement work in 1938.

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Appendix

TABLE A

Development of fruit, seed and embryo in mango, 1938

		Dates																	
		March		April				May				June					July		
		23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20
Bombai	Fruit	Length cm.	0·96	...	4·40	5·60	6·90	7·40	8·60	9·50	10·20	10·70								
		Volume c.c.	0·90	...	25·30	53·30	90·50	117·5	149·4	206·7	255·40	257·60								
	Seed	Length cm.	0·50	...	1·70	3·00	4·00	4·80	5·00	6·20	6·70	6·60								
		Volume c.c.	0·10	...	0·90	3·90	7·90	12·10	14·10	20·80	22·00	27·00								
	*Embryo	Length cm.	...	0·80	1·50	2·70	3·90	4·70	5·70	6·20	6·50	6·30								
	Radicle & plumule	Length cm.	...	0·26	2·22	0·26	0·38	0·45	0·53	0·56	0·61	0·71								
Langra	Fruit	Length cm.	1·39	...	3·09	4·86	5·94	7·60	8·20	8·60	8·60	7·20	8·70	9·20	9·40	9·70	9·30	9·30		
		Volume c.c.	1·51	...	10·89	36·55	62·20	106·2	137·6	160·0	171·4	205·60	205·0	217·0	237·0	243·0	252·0	271·0		
	Seed	Length cm.	0·56	...	1·20	1·92	2·65	3·70	4·90	5·10	5·20	5·40	5·50	5·32	5·70	5·70	5·90	6·10		
		Volume c.c.	0·07	...	0·24	0·91	2·20	4·60	7·70	8·70	10·00	10·50	11·10	11·70	12·00	12·30	12·30	12·49		
	*Embryo	Length cm.	...	0·41	1·05	1·80	2·63	3·72	5·27	5·30	5·47	5·21	5·15	5·18	5·68	5·73	5·29	...		
	Radicle & plumule	Length cm.	...	0·06	0·11	0·24	0·27	0·37	0·50	0·46	0·58	0·50	0·50	0·47	1·94	1·96	1·94	...		
Fazli	Fruit	Length cm.	1·56	...	2·80	5·89	7·34	7·83	9·80	11·50	12·60	14·30	14·00	15·16	15·40	15·65	15·90	16·12	16·34	16·22
		Volume c.c.	1·93	...	7·80	48·85	87·70	102·1	170·4	277·5	349·7	450·0	518·0	628·0	642·00	650·2	658·3	708·2	724·9	775·0
	Seed	Length cm.	0·68	...	1·10	2·53	5·32	4·05	5·50	5·90	6·60	6·80	6·80	6·66	6·90	7·30	7·03	7·92	7·58	7·91
		Volume c.c.	0·36	...	1·26	2·19	4·07	4·35	10·10	15·00	20·00	21·00	21·00	21·80	26·70	29·20	32·0	32·70	36·60	38·10
	*Embryo	Length cm.	...	0·67	0·95	2·20	3·25	3·71	5·27	5·52	6·48	6·51	5·98	8·79	7·14	7·06	7·18	7·10	6·93	7·72
	Radicle & plumule	Length cm.	...	0·16	0·23	0·30	0·38	0·40	0·45	0·55	0·61	0·60	0·81	0·87	3·59	6·46	6·73	6·69	10·91	12·20

* Length in reality represents cotyledon length. No volume was measured in 1938.

TABLE B

Development of fruit, seed and embryo in mango, 1939

			Dates															
			March		April				May				June					July	
			23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13
Bombai		Length cm.	...	3·31	4·17	5·79	5·88	6·14	7·68	8·17	7·82	8·41	8·50						
		Volume c.c.	...	11·72	18·20	53·60	57·60	75·00	126·6	54.7	154 7	168·8	175·6						
	Seed	Length cm.	...	1·36	2·03	3·65	3·90	4·28	5·54	5·80	5·66	5·72	5·74						
		Volume c.c.	...	0·39	1·33	5·10	6·84	11·60	13·60	15·86	15·50	16·40	16·00						
	*Embryo	Length cm.	...	1·20	1·68	3·28	3·78	4·16	5·40	5·60	5·60	5·60	5·80						
		Volume c.c.	...	0·16	0·72	3·98	5·74	10·40	12·90	14·40	14·20	15·20	13·80						
	Radicle & plumule	Length cm.	...	0·05	0·15	0·27	0·36	0·46	0·40	0·50	0·33	0·28	0·52						
Lanka	Fruit	Length cm.	...	2·83	5·07	5·83	6·42	7·04	7·13	7·72	8·57	8·54	8·74	8·56	9·74	9·94			
		Volume c.c.	...	5·64	40·50	56·60	80·80	120·0	121·4	129·2	211·2	216·0	235·0	239·8	240·6	245·0			
	Seed	Length cm.	...	1·10	2·37	3·10	4·30	5·40	4·48	5·06	5·97	5·68	5·84	5·70	5·82	6·18			
		Volume c.c.	...	0·24	1·80	3·28	8·62	12·90	12·00	12·60	1 ·83	15·00	17·20	17·60	20·10	20·60			
	*Embryo	Length cm.	...	0·73	2·24	2·96	4·10	5·32	4·76	5·02	5·90	5·66	5·71	5·60	5·50	6·00			
		Volume c.c.	...	0·06	1·30	2·36	7·12	11·80	11·10	11·60	12·60	14·00	14·40	15·50	15·30	17·00			
	Radicle & plumule	Length cm.	...	0·06	0·44	0·39	0·38	0·36	0·30	0·48	0·38	0·37	0·34	1·14	1·17	1·40			
Hazi	Fruit	Length cm.	2·10	2·35	4·26	5·50	6·56	6·52	9·20	10·10	16·60	11·50	12·54	16·40	15·20	15·12	15·02	15·20	14·20
		Volume c.c.	3·60	4·80	21·40	43·40	66·00	70·00	180·8	271·0	346·7	327·0	423·0	535·0	625·6	689·0	772·0	775·0	827·0
	Seed	Length cm.	0·90	1·00	2·07	2·70	3·48	3·56	6·40	5·56	6·36	5·72	6·52	6·74	7·62	7·50	7·51	7·39	7·83
		Volume c.c.	0·24	2·22	0·96	2·20	3·26	3·68	13·07	15·33	18·66	15·40	18·30	17·40	20·20	21·60	24·80	26·40	28·80
	*Embryo	Length cm.	0·57	0·45	1·87	2·54	3·28	3·36	4·80	5·44	6·30	5·60	6·64	6·72	7·16	7·30	7·00	7·25	7·67
		Volume c.c.	0·05	0·05	0·61	1·50	2·30	2·76	11·80	13·80	14·60	14·40	16·70	16·20	18·10	19·20	22·40	24·50	26·90
	Radicle & plumule	Length cm.	0·05	0·10	0·19	0·26	0·35	0·32	0·42	0·42	0·62	0·61	0·76	3·39	3·52	3·59	5·52	10·00	12·4

* Length in reality represents cotyledon length.

THE EFFECT OF AMMONIACAL AND NITRATE NITROGEN ON THE YIELDS OF THE RICE PLANT

BY

R. H. DASTUR

Punjab Agricultural College, Lyallpur

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DURING the investigations on the physiology of the rice plant carried out at Bombay it was found that from water-culture solutions the absorption of ammoniacal nitrogen by the rice plant decreases while that of the nitrate nitrogen increases as the plant ages [Dastur and Malkani, 1933]. It was, therefore, concluded that a mixture of two forms of nitrogen would be a better source of available nitrogen to the rice plant than any one of them applied singly, after transplantation. Pot experiment and small plot experiments later confirmed the above conclusion [Dastur and Pirzada 1933]. It was also found that maximum effect on the growth and yield of the rice plant was produced when a mixture of sulphate of ammonia and potassium nitrate was applied one month after transplantation (i.e., middle of August).

When the above-mentioned findings were discussed by the Rice Sub-Committee of the Imperial Council of Agricultural Research, it was suggested that the superiority of the mixture of ammonium sulphate and potassiulm nitrate to any one of the two fertilizers applied on an equal nitrogen basis might be due to the presence of potassium and not to the greater availability of nitrogen in the mixture used. In order to meet this fresh view point it was decided to use sodium nitrate in place of potassium nitrate. Field experiments with necessary replications were therefore arranged at two places in the Bombay Presidency with the following four treatments which were randomised ; (A) control, (B) sodium nitrate, (C) ammonium sulphate and (D) mixture of (B) and (C) on equal nitrogen basis. Nitrogen was applied at the rate of 40 lb. of nitrogen, in all cases, one month after transplantation. The results of these field experiments as given in Table I showed that in the light soils at Goregaon (Thana district) the mixture of ammonium sulphate and sodium nitrate gave significantly higher yields of grain than ammonium sulphate or sodium nitrate alone while the increase in grain yield resulting from ammonium sulphate over that of the control was just on the verge of significance. No significant difference was found between the grain yields from sodium nitrate and the control. The yields of straw on Goregaon soils were in the order :—mixture>ammonium sulphate>sodium nitrate>control. On heavy soils at Talangpur (Surat district) the case was different. On these soils ammonium sulphate was found superior to the mixture of two fertilizers and gave a significant increase in yields of grain. The mixture gave higher yields than sodium nitrate and sodium nitrate gave higher yields than the control.

In case of straw yields ammonium sulphate was found equal to mixture while the other treatments gave similar results as on soils at Goregaon.

From the results obtained it was clear that at one place the mixture proved better than ammonium sulphate while at the second place ammonium sulphate gave higher yields than the mixture treatment. It was then suggested

by the author that these differences in response to these two treatments at these two places might be due to the differences in the physical and chemical properties of the soils (*Prog. Reports, I. C. A. R.*, 1934).

TABLE I

Place	Treatments	Mean yields of grains in lb. per acre	Mean yields of straw in lb. per acre	Conclusions
Goregaon (Thana district), Bombay	A. Control	1,382	1,894	Mixture is superior to ammonium sulphate
	B. 40 lb. of N as sodium nitrate	1,306	2,265	
	C. 40 lb. N as ammonium sulphate.	1,516	2,983	
	D. 20 lb. N as sodium nitrate + +20 N as ammonium sulphate.	2,001	3,582	
	S. E. of a single mean . .	55·9	73·1	
Talangpur (Surat district), Bombay	A. Control	1,505	1,842	
	B. 40 lb. N as sodium nitrate .	1,685	2,276	Ammonium sulphate is superior to mixture
	C. 40 lb. N as ammonium sulphate.	2,276	3,150	
	D. 20 lb. N as sodium nitrate +20 lb. N as ammonium sulphate.	2,033	2,919	
	S. E. of a single mean . .	124·0	212·0	

In 1934 the above quoted results were discussed by the Rice Sub-Committee of the Imperial Council of Agricultural Research and it was then recommended that the Agricultural Departments of the different provinces may find it worthwhile to test this conclusion of superiority of a mixture of ammonium sulphate and sodium nitrate on some soils to either constituent as a fertilizer for rice.

The investigations at Bombay could not be continued on account of the transfer of the author to the Punjab and further investigations on the properties of the soils giving different responses to the mixture treatment as compared with ammonium sulphate could not be undertaken. But in view of the recommendations of the Imperial Council of Agricultural Research the Agricultural Departments of some provinces laid out field experiments to test the above-quoted conclusion.

The yield results of the field experiments carried out at different agricultural stations in India have now been made available to the author for examination in the light of the conclusions reached by him at Bombay.

The field experiments were carried out at the agricultural research stations in Assam, United Provinces, Bombay, Orissa, Bihar, Madras and in Travancore State. The experiments were either conducted for one, two or three consecutive years in each province at one or more places. It may be mentioned here that experiments laid out at different places differed in one or more respects from one another. As for instance at Raipur in C. P. treatments given were different from those recommended. The doses of nitrogen given also varied, and so also the time of applications of the fertilizers. The number of replications differed at different places. On account of lack of homogeneity in the conduct of experiments no further statistical study of the results than discussed below was possible.

The yield results with conclusions in brief are given in Tables II-IV. A study of these results show a few irregular features which are pointed out later.

TABLE II

Treatments	Mean yields per acre in lb.	Conclusions
TITABAR (ASSAM) *1932*		
A. Control . .	2,674	Mixture is superior to amm. sulphate.
B. 40 lb. N as pot. nitrate.	2,770	
C. 40 lb. N as amm. sulphate.	2,475	
D. 20 lb. N as pot. nitrate + 20 lb. N. as amm. sulphate.	2,875	
MUGHAD (BOMBAY) *1935*		
A. Control . .	2,057	*No effect of treatments.
B.* ———	...	
C. 40 lb. of N as amm. sulphate.	1,997	S. E. not stated.
D. 20 lb. N as sod. nitrate + 20 lb. N as amm. sulphate.	1,997	

Treatments	Mean yield per acre in lb.	Conclusions
NAGINA (U. P.) *1935*		
A. Control . .	2,234	Mixture is as good as amm. sulphate alone.
B. 50 lb. N as sod. nitrate.	2,181	
C. 50 lb. N as amm. sulphate.	2,535	S.E. = 124·8 lb.
D. 20 lb. N as sod. nitrate + 20 lb. N as amm. sulphate.	2,617	
1936		
A.	2,311	Amm. sulphate alone is as good as mixture.
B. Same as above .	2,554	
C.	3,112	S. E. = 70·1 lb.
D.	2,937	

Treatments	Mean yields per acre in lb.	Conclusions
CUTTACK (BIHAR) *1935*		
A. Control . .	3,373	Amm. sulphate alone is as good as mixture.
B. 40 lb. N as sod. nitrate.	3,537	
C. 40 lb. N as amm. sulphate.	3,772	S.E. = 145·17 lb.
D. 20 lb. N. as sod. nitrate + 20 lb. N as amm. sulphate.	3,656	
1936		
A.	1,980	Amm. sulphate is as good as mixture.
B. As above . .	2,311	
C.	2,478	S.E. = 72·4 lb.
D.	2,344	

TABLE III

Mean yields per acre in lb.

Treatments	1933-34		1934-35		1935-36		Conclusions
	Sandy soil	Clayey soil	Sandy soil	Clayey soil	Sandy soil	Clayey soil	
Raipur (C. P.)							
1. 20 lb. N as amm. sulphate at transplantation.	1,011	933	1,475	1,025	2,084	...	No effect of treatments.
2. 10 lb. N + 10 lb. N as amm. sulphate at transplantation and at flowering.	949	586	1,349	1,103	1,988	...	
3. 10 lb. N as amm. sulphate + 10 lb. N as sodium nitrate at transplantation.	973	624	1,347	1,098	1,998	...	
4. 10 lb. N as amm. sulphate at transplantation + 10 lb. N as sodium nitrate at flowering.	998	569	1,378	1,048	1,991	...	
	S. E. not given		S.E. 132 lb.	162·9 lb.	148·2 lb.		

Kanke (Bihar)

	1935-36		1936-37		1937-38		
	Transplanted	Broadcast	Transplanted	Broadcast	Transplanted	Broadcast	
A. Control	311	661	1,219	1,086	302	756	In 1935-36 and 1936-37 amm. sulphate is superior to mixture but in 1937-38 mixture is found superior to amm. sulphate. In 1937-38 sodium nitrate is found to be the best treatment.
B. 40 lb. N as sodium nitrate.	513	486	1,361	1,095	1,210	1,473	
C. 40 lb. N as amm. sulphate.	428	804	1,890	2,135	681	1,176	
D. 20 lb. N as sodium nitrate + 20 lb. N as amm. sulphate.	408	466	1,509	1,576	717	1,436	
	S. E. not known						

At Mughad in Bombay yields show no effect of treatments. The yields of control are slightly higher than the plots treated with 40 lb. of nitrogen and will therefore be not discussed. The results obtained at Raipur in the Central Provinces could not be correctly interpreted as no control is provided for and it is difficult to know if application of nitrogen in any form has any effect at all. The results obtained at Kanke indicate great differences in the responses to sodium nitrate. In 1935-36 sodium nitrate has given the highest yields in case of transplanted paddy but in case of broadcast paddy the same treatment has depressed the yields. In 1937-38 on the other hand

sodium nitrate has proved the most superior treatment in both cases, while in 1936-37 this is not the case. It is likely that in 1935 in case of broadcast paddy sodium nitrate may have caused injury to the rice seedlings at the time of application and thus the yields were depressed. Such injury to plants is known to be caused when sodium nitrate is applied.

TABLE IV

Treatments	Coimbatore	Maruteru	Adutural	Berhampur	Conclusions
	Yields expressed as percentages of general mean for 1935-36 and 1936-37				
A. Control	125·7	98·1	123·3	70·9	Amm. sulphate is as good as the mixture.
B. 30 lb. N as sodium nitrate	134·5	69·5	139·2	80·5	
C. 30 lb. N as amm. sulphate	157·8	69·9	152·4	90·0	
D. 15 lb. N as sodium nitrate +15 lb. N as amm. sulphate.	149·4	70·5	147·5	90·0	
E. 20 lb. N as amm. sulphate +10 lb. N as sodium nitrate.	153·1	69·8	144·8	84·6	
F. 10 lb. N as amm. sulphate +20 lb. N as sodium nitrate.	139·7	70·7	146·5	82·2	
	S. E. = 3·6	Critical difference = 10·2			

In Madras the experiment to determine the response to a mixture of two fertilizers was laid out for two years 1935-36 and 1936-37 at four different agricultural stations. In addition to the usual four treatments two more combinations of ammonium sulphate and sodium nitrate were tried as separate treatments. At Maruteru Farm the experiment was spoiled in 1936-37 on account of the incidence of silver shoot disease and controls yielded more than the plots treated with nitrogen.

Table V shows how the mixture and ammonium sulphate treatments have responded at different places in different provinces in different years.

TABLE V

Mixture > amm. sulphate	Goregaon (Bombay)	Titabar (Assam)	Kanke (Bihar)	Travancore
	1933-34	1932	1937-38	1936-37
Amm. sulphate > mixture	Kanke (Bihar)	Talangpur (Bombay)		
	1935-36 1936-37	1933-34		
Mixture = amm. sulphate	Nagina (U. P.)	Cuttack (Orissa)	Raipur (C. P.)	Madras
	1935-36 1936-37	1935-36 1936-37	1933-34 1934-35	1936-37
Sodium nitrate > amm. sulphate = mixture	Kanke (Bihar)			
	1937-38			

The responses to the mixture and ammonium sulphate at different places are different. At four stations mixture was found superior to ammonium sulphate in a total of six experiments. There was no difference between the mixture and ammonium sulphate in a total of twelve experiments at six stations while ammonium sulphate was found superior to mixture in a total of five experiments at two stations. There was no response to any fertilizer at one station while it is not possible to say whether there was any response to applications of nitrogen at another station. At the latter place no difference between the mixture and ammonium sulphate treatments was found. Thus mixture was found superior to ammonium sulphate in six experiments out of a total of twenty-nine experiments, inferior to ammonium sulphate in five experiments and equal to ammonium sulphate in twelve experiments. It is thus clear that responses to mixture and ammonium sulphate varied from place to place as was the case in the field trials carried out by the author at two places in Bombay.

The results suggest that the differences in the response to these treatments at different places may be due to the differences in the physical and chemical properties of the soil. They may also be due to the different effects produced by the sodium ions of sodium nitrate in different soils. It was pointed out in the earlier part of the paper that originally a mixture of ammonium sulphate and potassium nitrate was used but to meet the view point that greater response given by the mixture to either constituent might be partly due to the presence of potassium ions in the mixture, potassium nitrate was replaced by sodium nitrate. But this change from potassium nitrate to sodium nitrate very likely introduced other disturbances in the soil. It is known that from a solution of sodium nitrate, nitrate ion is absorbed to a greater extent than sodium ions and the soil reaction is altered as found by the author [Dastur and Kalyani, 1934]. In case of potassium nitrate this is not the case. It was found by the author [Dastur and Malkani, 1933] that potassium ion is absorbed by the rice plant to a greater extent than the nitrate ion from a solution of potassium nitrate. It is thus possible that presence of sodium nitrate in the mixture may have adversely affected the activities of the roots in certain soils and has thus lessened the yields at some places.

The above-mentioned point can be elucidated by laying out a complex experiment involving all combinations of potassium nitrate, sodium nitrate and ammonium sulphate. There will be $(2)^3$=eight treatments: (1) control; (2) potassium nitrate; (3) sodium nitrate; (4) ammonium sulphate; (5) potassium nitrate+sodium nitrate; (6) sodium nitrate+ammonium sulphate; (7) potassium nitrate+ammonium sulphate; (8) potassium nitrate+sodium nitrate+ammonium sulphate. Such an experiment will at once show the effects produced on the plants by the presence of potassium and sodium ions in the mixture.

Summary

Field trials on rice were arranged to study the response made by sulphate of ammonia, sodium nitrate and a mixture of two fertilizers, on equal nitrogen basis at different places in India to test the authors' finding from a purely physiological study, that mixture of two fertilizers is a better source of nitrogen in some soils than any one of the two constituents used separately.

The experiments were laid for two or three years in Bihar, Orissa, Centra Provinces, Madras, Bombay, Assam and Travancore during the period 1933-37. The statistical analyses of the results showed that the mixture gave significantly higher yields than ammonium sulphate at Goregaon (Bombay), Titabar (Assam), Kanke (Bihar) and Travancore ; ammonium sulphate gave significantly higher yields at Kanke (Bihar) and Talangpur (Bombay) ; the mixture was found as good as ammonium sulphate at Nagina (U. P.), Cuttack (Orissa), Raipur (C. P.) and Coimbatore, Aduturai and Berhampur (Madras). Sodium nitrate gave significantly higher yield than the mixture or ammonium sulphate at Kanke (Bihar) in 1936-37. The field experiments arranged at two places in Bombay by the author had also shown that the response to the mixture and ammonium sulphate varied in different soils.

It is suggested that presence of sodium ions in sodium nitrate used may have produced some deleterious effects in certain soils and thus the response to mixture may have been lessened at such places resulting in no increase in the yields when compared with ammonium sulphate. A complex experiment involving all combinations of potassium nitrate, sodium nitrate, ammonium sulphate and control will elucidate this point in such soils.

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CARBON TRANSFORMATIONS DURING THE DECOMPOSITION OF CANE MOLASSES UNDER SWAMP SOIL CONDITIONS

BY

G. NARASIMHAMURTHY

Department of Biochemistry, Indian Institute of Science, Bangalore

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(With one text-figure)

LABORATORY studies on the effect of addition of cane molasses to various representative Indian soils under swampy conditions have shown that carbohydrate, the major constituent of molasses, rapidly undergoes decomposition, yielding a variety of products, some of which escape into the air as gases, the others remaining in solution [Bhaskaran *et al.*, 1934, Karunakar *et al.*, 1937]. To understand the nature of the decomposition products contributing to the fertilizing value of the molasses, it becomes necessary to carry out a systematic examination of such products throughout the period during which the fermentation is in progress. The results of the studies relating to the gaseous products of the breakdown of the soil molasses complex have already been published [Narasimhamurthy, 1936]. An examination of the soil residues [Narasimhamurthy and Subrahmanyan, 1935] in these studies revealed that the final carbon level remained unaltered except in those cases where the system was alkaline. In this latter case, the carbon level fell down to a great extent. In the initial stages of the fermentation, however, there is a distinct rise in the carbon level of the soil. It is therefore clear that the significant changes are confined to the solution phase and in this paper the results of a detailed study of the changes in carbon complex in the solution phase are recorded.

Experimental

Materials

For these studies, the local red sandy loam soil was employed. After removing the roots and other vegetable residues present in it, the soil was pulverised and sieved. The fraction which passes through 20 mesh but not through 30 mesh was separated out for reasons given in our previous work [Bhaskaran *et al.*, 1934] for use in the experiments. The soil used in the present study was obtained from the same plot from which samples had been drawn for the previous investigations [Bhaskaran *et al.*, 1934]. The experiments were carried out during the months of August-September and the temperature during the period varied between 90° and 70°F.

Procedure

The soil was weighed out in 400 gm. lots into bottles of about 2 litres capacity. To each lot was then added 4 gm. of molasses and one litre of water. This proportion of water was found sufficient to keep the soil well submerged. The bottles were loosely plugged with cotton wool. Two series of experiments were conducted. The first, which was qualitative in character, had for

its objective the identification of the products of decomposition in the liquid phase. This experiment lasted for four weeks and random samples were taken for examination each day in the first week and once a week later. In the second series, the more important constituents were quantitatively estimated ; samples were taken for analysis every other day throughout the period.

The supernatant liquid was separated from the soil residue by filteration on a Buchner under gentle suction. The residue on the filter was washed three times with liberal quantities of distilled water and the combined filtrate and washings employed for the analysis. The solution was first made alkaline in order to precipitate iron and after filtration and repeated washing of the precipitate, the filtrate and washings were distilled to remove the neutral volatile products. Ice-cold water was employed to cool the receiver and the condenser. The distillate was made up to a known volume and aliquots used for estimating alcohol and aldehyde. The residual solution in the distilling flask was quantitatively transferred into a clean porcelain basin, made alkaline to litmus and evaporated on a water-bath to a small bulk. It was then made up to a known volume and aliquots used for estimating lactic acid and volatile fatty acids.

Methods

Qualitative examination revealed the presence of the following acids :— lactic, acetic, propionic and butyric. Alchol and aldehyde were the only neutral bodies detected.

Alcohol and aldehyde.—Aldehyde was estimated by the method of Fidler [1934]. Briefly stated, the method consists in treating the aldehyde solution with sodium bisulphite at 0°C. for one hour and back-titrating the unused bisulphite with standard iodine solution. The observation of Fidler [1934], that under these conditions auto-oxidation of aldehyde is negligible, is confirmed in the present work. It was also found that alcohol does not interefere in the estimation.

Alcohol and aldehyde were together estimated in a separate aliquot. They were oxidised by excess of standard dichromate solution at 37°C. in an incubator for forty-eight hours, the residual dichromate being estimated by titration with standard thiosulphate. Subtracting from this the known value for aldehyde, the quantity of alcohol present in the mixture was computed.

Lactic acid.—The method was essentially the same as that outlined by Subrahmanyan [1929]. Preliminary experiments showed that the method was quite suitable for the determination of lactic acid in the decomposition products of molasses, and that the presence of volatile fatty acids, such as propionic and butyric acids, did not interfere with the accuracy of the method.

Fatty acids.—Volatile fatty acids were estimated according to the procedure outlined by Dyer [1916].

Results

For the qualitative study the culture solution was examined both before and after separation from the soil sediment. In the latter the solution was fractionated into three portions through distillation : (1) the non-volatile residue in the flask, (2) the volatile acids and (3) the volatile neutral products of fermentation. In the non-volatile portion, tests were made for lactic, peruvic and succinic acids. Volatile fatty acids were looked for in the

second fraction and tests were applied to the third portion for acetone bodies alcohols and aldehydes among the netutral volatile products.

Reducing sugars persisted till the third day. Lactic acid and alcohol were present in the solution after the first twenty-four hours. The solution also gave a faint idoform reaction in the cold indicating the presence of acetone bodies, but other tests showed that this was not due to acetone. The reaction was noticed on the second day also but subsequent samples did not answer this test. On the second day, in addition to lactic acid and alcohol, both propionic acid and acetic acid were present, the latter only in traces. The following day aldehyde was the only additional compound identified ; the test for acetic acid was stronger than on the second day. The same tests were obtained throughout the week with only one addition, viz. that of butyric acid which appeared to be in traces. The indication for aldehyde was also weak. During the following two weeks the products persisted with the exception of aldehyde and butyric acid. Towards the end of the last week of the experiment, i.e. on the twenty-eighth day, only three products were found to be present and these were alcohol, lactic acid and acetic acid. They too were present only in diminished quantities.

In the other series, where a quantitative estimation of the fermentation products was carried out, the experimental period was restricted to about three weeks, the reason being that in actual field practice the fields are flooded after this period, and the soluble products get completely washed away. In these estimations attention was given to aldehyde, alcohol, lactic, acetic, propionic and butyric acids. The results are given in Table I and graphically represented in Fig. 1. The quantities of aldehyde and butyric acid in the solution being of the order of 1 mg. and below were omitted from the table.

TABLE I

Balance sheet for carbon in the changes accompanying the decomposition of molasses (expressed on 100 gm. of soils)

Serial No. of experiment	Period of fermentation in days	Total carbon added as molasses (mg.)	Carbon recovered as						
			Sugar	Alcohol	Acetic acid	Propionic acid	Lactic acid (mg.)	Carbon dioxide* (mg.)	Total carbon recovered (mg.)
1	0	307	...	...	...	...	...	...	307
2	2	„	31	64·5	13·2	17·4	31·5	22.0	...
3	4	„	Nil	16·5	22·0	97·7	36·0	66.0	238·4
4	6	„	„	20·0	12·0	40·5	47·7	90·5	211·0
5	8	„	„	9·0	...	...	...	100.0	...
6	10	„	„	7·0	58·7	134·0	21·7	103.0	324·5
7	12	„	„	4·0	111·0	79·0	20·5	106.0	320·7
8	14	„	„	2·5	83·5	107·0	22·2	107·4	322·6
9	16	„	„	0·6	85·0	136·0	13·6	109·0	344·3
10	18	„	„	0·9	104·0	98·7	19·0	111·2	333·9
11	20	„	„	1·3	66·0	118·0	12·0	114·0	311·5
12	22	„	„	0·9	80·0	118·0	8·5	120·5	323·0

* Results in this column are reproduced from a previous paper [Bhaskaran *et al.*, 1934].

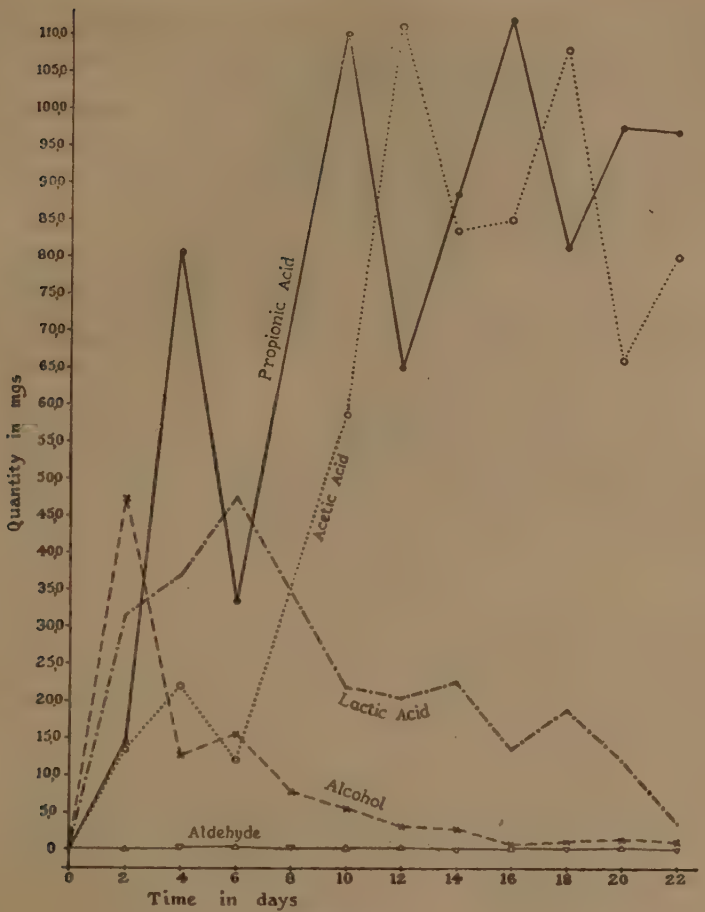

FIG. 1.

DISCUSSION

The results presented show that the carbonaceous matter of molasses is largely converted into gases like carbon dioxide and methane and other organic compounds which being soluable are present in the supernatant liquid. The carbon content of the soil is not, however, enhanced as there is little or no humus production. This observation is in conformity with the previous findings [Narasimhamurthy and Subrahmanyan, 1935].

Of the several soluble compounds formed, organic acids form the bulk and the quantity produced particularly that of acetic and propionic acids is considerable during the second half of the experiment. The large amounts of acids present lowers the *p*H markelly, rendering the soil highly acidic. This is in conformity with the observations in the earlier work [Bhaskaran *et al.*, 1934] wherein it was shown that the *p*H and buffering capacity of the supernatant liquid reach a peak by about this period. Due to this acidity no crop can thrive on the soil during this period. The toxic effect ascribed to molasses-treated soil and the unfavourable results reported by Peck [1912], Harrison and

Wad [1913] may be due to this condition. Karunakar *et al.* [1937] ascribe the toxicity to the gases carbon dioxide and hydrogen which displace oxygen from the soil solution and thus as phyxiate the plant.

The presence of these acids in such concentrations would naturally alter the physical condition of the soil by reacting with its insoluble mineral complex. Considerable quantities of iron, calcium and aluminium are brought into solution [Bhaskaran *et al.*,1934].

Of considerable interest are the chain of fermentation products produced under the conditions of the experiment, in the succession mentioned already. Lactic acid is the first to be produced. The other acids are probably derived from it as a result of decomposition. The observation that the concentration of volatile acids increases with the decrease in the concentration of lactic acid lends support to this assumption. However a definite assertion on this point is not possible with the available data.

In view of the high carbon-nitrogen ratio obtaining in molasses, there is considerable loss of carbon. If by the addition of suitable nitrogenous matter, the C/N ratio is narrowed down, a portion of carbon could probably be retained in the soil but this however is a field for further investigation.

Summary

1. The transformation of molasses, when applied to soil as a manure under waterlogged conditions, has been studied.

2. The carbon reserves of the soil are not augmented by using molasses as a manure. The acidity of the supernatant solution becomes so high as to render the soil unsuitable for the crop for at least one month after the application of molasses.

3. The decomposition products are mostly acids such as lactic, acetic, propionic and butyric, the last mentioned occurring only in traces. Alcohol is also found to occur in appreciable quantities These decomposition products together with carbon dioxide which escapes from the system as gas account for nearly all the quantity of carbon added as molasses.

4. Lactic acid is the first product of the decomposition of molasses in soil. Other products appear later. The concentration of lactic acid gradually decreases while that of other acids increase.

The author's grateful thanks are due to Prof. V. Subrahmanyan for his helpful suggestions in the course of this investigation and to Mr B. N. Banerjee fo his kind interest.

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ON THE INDEX OF NITROGEN LEVEL IN SOILS

BY

P. E. LANDER, D. Sc., F. I. C., I. A. S.

Agricultural Chemist to Government, Punjab Lyallpur

AND

M. R. MADHOK, Ph. D., Assoc. I. A. R. I.

Agricultural Bacteriologist, Punjab Agricultural College, Lyallpur

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SINCE the discovery of nitrogen-fixing bacteria, workers in many countries have made attempts to evaluate the extent and significance of nitrogen fixation in soils under different conditions. There are cogent reasons to believe that fixation occurs in arable soils and the most direct proof is the continuous crop yields from soils which have never been manured within human memory. Potash is abundant in most soils and phosphoric acid can be brought from the sub-soil by the deeper roots of plants, so a fair level of fertility can be maintained if the nitrogen supply is kept up. In soil where no nitrogenous manure has been added the supply of nitrogen must be entirely due to nitrogen-fixing organisms.

The extent of asymbiotic nitrogen fixation has been fixed within considerable limits in the vast literature on the subject. Two plots at the Rothamsted Farm have shown an average fixation of 25 lb. of nitrogen per acre annually over a period of twenty-five years [Hall, 1937], while another plot left wild under permanent vegetation on the same farm has shown an average annual fixation of 91·7 lb. nitrogen per acre during fifty years [Russell, 1937]. In the Punjab, Wilsdon and Ali [1922] recorded an increase of over 100 per cent nitrogen in four months in some districts ; the maximum fixation recorded being 50 mg. nitrogen per 100 gm. soil or equivalent to 150 tons farmyard manure per acre. Lander and Ali [1925] from the same laboratory corroborated the above findings on the nitrogen-fixing power possessed by arable soils, but were not able to record such high additions. They on the other hand found that losses of the nitrogen fixed also took place as rapidly.

Considering the losses of nitrogen otherwise than by leaching from arable soils, one plot at Rothamsted has received an application of 14 tons of farmyard manure or 200 lb. nitrogen every year since 1865 ; of this huge amount of nitrogen only about one-fourth has been obtained in the crop, another one-fourth is detectable in the soil and the rest is supposed to have been lost.

Besides the innumerable reports of gains and losses of nitrogen from arable soils there are instances on record where no significant fixations or losses could be recorded [Punjab Department of Agriculture Reports, 1917-20]. While there can be several explanations of differences in observations under different conditions, the chief reason for such widely differing observations seems to be

the method that is commonly used for the determination of nitrogen in soil. That most commonly used is the Kjeldahl method which is based on the transformation by acid digestion of the different forms of nitrogen into ammonium sulphate from which ammonia is later distilled in standard acid. Generally 5 to 10 gm. of soil samples are used for analysis and the ammonia evolved during distillation is received in a deci-normal acid.

In actual practice it is possible even with the utmost care to use a drop of alkali too much or too little before the end point is well marked in titration. Taking four million pounds as the average weight of an acre-foot soil this difference of a drop of alkali in titration represents 56 lb. of nitrogen more or less per acre if a 5-gm. sample is used for analysis or 28 lb. nitrogen if the sample taken for analysis is 10-gm.

(Approximate weight of one acre-foot soil

$$= 4{,}000{,}000 \text{ lb.}$$

$$\text{or} \times 453 = 1{,}812{,}000{,}000 \text{ gm.}$$

Difference of a drop of deci-normal alkali for 5-gm. sample means a difference of one c.c. in 100 gm.— or 1·4 mg. N per 100 gm. soil

$\therefore$ difference in acre-foot soil—

$$= \frac{1{,}812{,}000{,}000 \times 1{\cdot}4}{1000 \times 100}$$

$$= 25{,}368 \text{ gm. N}$$

or 56 lb. N per acre)

Taking 45 lb. as the average nitrogen content of a wheat crop removed from one acre it will be seen that even the most careful worker cannot detect with certainty the gain or loss of this amount in the soil.

In order to illustrate this point a number of determinations were carried out with a sample of clay-loam soil. A portion of the sample was sieved through a 0·5-mm. sieve, another portion sieved through a 1-mm. sieve and still another portion sieved through 2-mm. sieve. Determinations of nitrogen were made in 5 and 10 gm. portions of the three samples so prepared and the following results were obtained :

NITROGEN IN LB. PER ACRE

I. As affected by the size of particles (10-gm. sample used for determination).

Sieve used	0·5 mm.	1 mm.	2 mm.
Dry digestion	1316	1330	1372
*Wet digestion	1372	1358	1400

II. As affected by the weight of sample taken for analysis (1-mm. sieved sample).

	Dry digestion	Wet digestion*
5 gm.	1400	1344
10 gm.	1330	1358

* In wet digestion the soil was treated with 20 c.c. water before the addition of acid.

Without discussing the comparative merits and demerits of the wet and dry methods of digestion or the influence of the weight and fineness of the sample taken for analysis, the above-quoted results clearly show how variable the results of nitrogen determination in soil can be in spite of neat care.

While standardization of the procedure similar to the one suggested by the Official Agricultural Chemists may help to make the results more comparable, the Kjeldahl method is not at all suitable for recording absolute fluctuations of nitrogen in soil.

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EUPELMELLA PEDATORIA FERR., A PARASITE OF THE COTTON-STEM WEEVIL (*PEMPHERES AFFINIS* FST.) FROM SOUTH INDIA

BY

P. N. KRISHNA AYYAR

Parasitologist, Agricultural College and Research Institute, Coimbatore

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(With Plate XXXV and three text-figures)

Introduction

IN the course of an investigation into the possibility of the biological control of the cotton-stem weevil of South India, the biology of *Eupelmella pedatoria* Ferr., an ectophagous larval parasite of this weevil, was studied. This curious eupelmid was for the first time observed parasitising *Pempheres* grubs in an off-season crop of Cambodia cotton during July 1937. It has since been recovered, though in small numbers, on several occasions from the same crop and from the same host as also from other hosts infesting a few other species of plants. The study is by no means exhaustive since many aspects of its biology and distribution still require a more thorough and extended investigation. This is perhaps the first record of this genus in India. Besides, the parasite was noted to be peculiar and unique in respect of certain structural characters, reproductive habits and parasitism. It was therefore thought desirable to place on record the fact of its occurrence in this country together with the observations so far made on its life-history and behaviour in relation to its host complex.

Adult (*Plate XXXV fig. 1*).—The adult female is a dark smooth shining elongate creature varying in size from 1·0 mm. to 3·6 mm. in length, averaging 2·6 mm. with a width varying from 0·5 mm. to 0·75 mm., averaging 0·6 mm. for six individuals. The general colour varies from brownish dark to jet black. The wings are rudimentary and curved with a narrow tapering apical region. Consequently the parasite is unable to fly. The parasites, however, are adepts in running quickly and taking long leaps in cages. The ovipositor is quite prominent and well extended beyond the tip of the abdomen.

The specimens were sent to the Imperial Institute of Entomology, London, for identification and Dr Ferriere has recently determined the same as a new species of *Eupelmella*—family Eupelmidae, super-family Chalcidoidea, [Ferriere, 1939].

History of the genus

The genus *Eupelmella* was first erected by Moore in 1919 and named *Eupelmus degeeri* Dalman as the genotype. As seen from available literature the genus appears to be small including so far only two species of economic importance, *Eupelmella vesicularis* Retz. and *E. platycleidis* Sarra. The

FIG. 1. Adult female (×12)

FIG. 2. Egg (×59)

FIG. 3. First stage larva (×40)

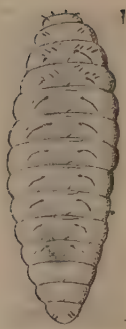

FIG. 4. Full-grown larva (×10)

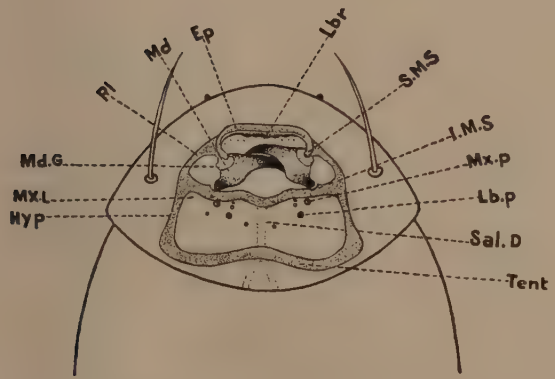

FIG. 5. Head and mouth-parts of full-grown larva

FIG. 6. Pupa (ventral view) (×12)

[Ep.=epistoma ; Hyp.=hypostoma ; I.M.S.=inferior mandibular strut ; Lbr.=labrum ; Pl.=pleurostoma ; S.M.S.=superior mandibular strut ; Md.=mandible ; Mxp.=maxillary palp ; Mdg.=Mandibular groove ; Lbp.=labial palp ; Tent.=tentorium. Sal. d.=Salivary duct

latter species is comparatively of minor importance since it has been recorded only as a parasite of the Tettigoniid—*Metrioptera grisea* F. in Italy [Sarra, 1934]. The other species *E. vesicularis* is of considerable importance as a primary parasite of the Hessian fly, *Mayetiola destructor* (Say). This species is highly polyphagous parasitising as it does a great variety of insect hosts representing diverse insect orders. The distribution of the species, however, is limited to Europe and North America. According to Dr Ferriere *E. pedatoria* is the first known oriental species of the genus *Eupelmella*. He also adds that there is the possibility of some species described in *Eupelmus* Dalm. coming under this genus since the differences between the two genera *Eupelmus* and *Eupelmella* have not been fully recognised. It is further pointed out that this Indian species is specially related to the European *E. mullneri* Ruschka, and the North African *E. schyzomyiae* Masi.

Distribution

So far as the present studies go, its distribution is confined to Coimbatore and surroundings. Further investigations may very likely disclose its presence in other localities in South India.

Hosts

The host range of the species appears to be restricted to Coleoptera and Hymenoptera so far as the writer's limited observations go. In nature, the species has been found to parasitise the full-grown grubs of *Pempheres* infesting Cambodia variety of cotton. Occasionally earlier stage grubs are also oviposited upon. It has also been reared from eggs and early instars of *Hypolixus* grubs boring into stems of amaranthus. There is a single representative of the species which has been reared by Mr V. Margabandhu from *Apion* grubs boring into a common weed, *Corchorus trilocularis*, found growing in and near cotton fields. In considering the host range it is of interest to note that the species ordinarily exists as a primary parasite, but in some cases can take up the role of a secondary or hyperparasite. In the course of the present studies it has been actually recovered as a hyperparasite from cotton fields on two occasions. First, on August 17, 1937, a newly hatched larva was taken feeding externally on a mature Eulophid larva—*Euderus pempheriphila* (Ramakrishna and Mani)—which is a primary parasite of *Pempheres* grubs. The parasite was again collected on the 24th of the same month as a small larva feeding on *Euderus* pupa. In laboratory trials it was found that no hosts other than *Pempheres* grubs were accepted for oviposition. *Hypolixus* grubs, *Euderus* larvae and pupae and various stages of other parasites, like *Dinarmus coimbatorensis* Ferr., etc. were supplied in cotton stalks and capsules for oviposition trials but with negative results. As seen in nature and from its ready acceptance of *Pempheres* in cages for oviposition and development it may be inferred that the stem weevil is its natural and normal host in South India.

Breeding technique

Oviposition experiments were conducted in ordinary 6 in. × 1 in. cotton plugged tubes with a daily supply of suitable host stages and food in the shape

of raisin or sugar or honey solution. The stages were safely lodged in artificial cells scooped out in fresh cotton stalks covered with a lid of thin bark and fastened by fine cotton threads. These stems were removed daily or as often as necessary and examined under a binocular. Development was studied in small gelatin capsules or paraffin cells into which parasitised stages were transferred to facilitate observations under a binocular. The rearing experiments were carried out in the laboratory at the Cotton Breeding Station during the period of July to December 1937. The temperature and humidity conditions of the period are graphically represented in Figs. 1-3.

Pre-oviposition period

The newly emerged adult female pays little or no attention to the host for about a minimum of seven days after emergence. During this period it either rests or feeds on the food supplies in the form of sugar solution or raisin and seldom interests itself in the loaded stalk supplied. This period was prolonged in some cases to a maximum of fourteen days as seen from the recorded data. The period averaged 9·5 days for six observed adults in the season August to December. A certain proportion of females was seen not to oviposit at all. Out of a series of twelve trials as many as six females, in spite of a prolonged life, failed to oviposit in laboratory trials, probably due to defective nourishment during their growing period.

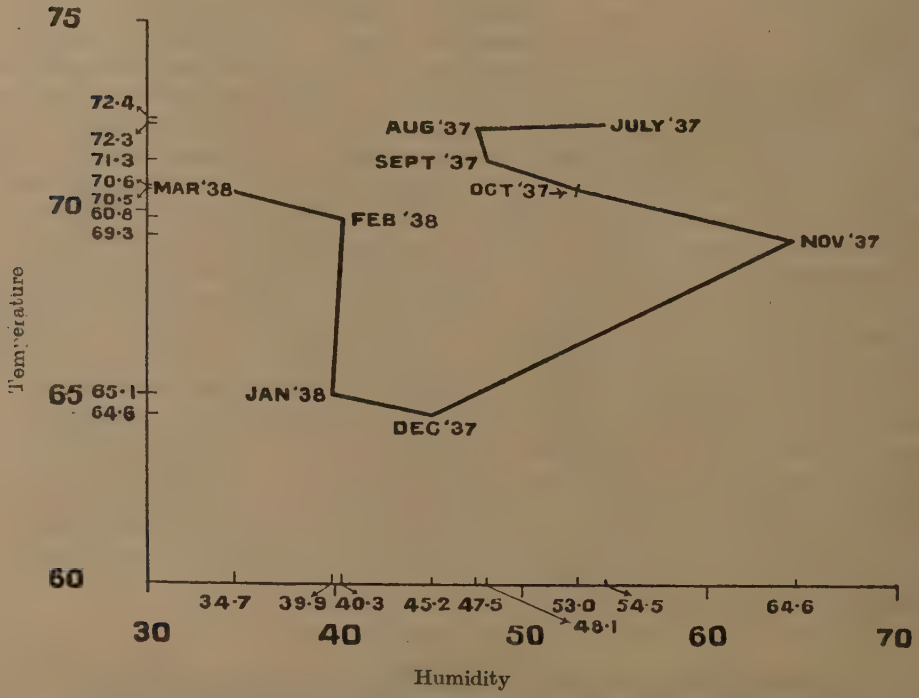

Fig. 1. Temperature and humidity curve 1937-38 (average minimum)

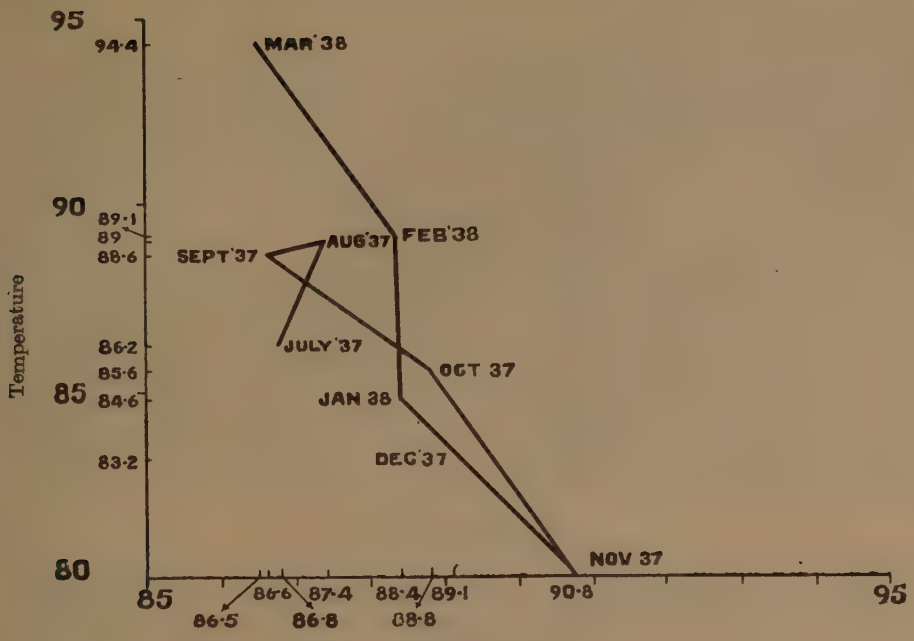

FIG. 2. Temperature and humidity curve, 1937-38 (average maximum)

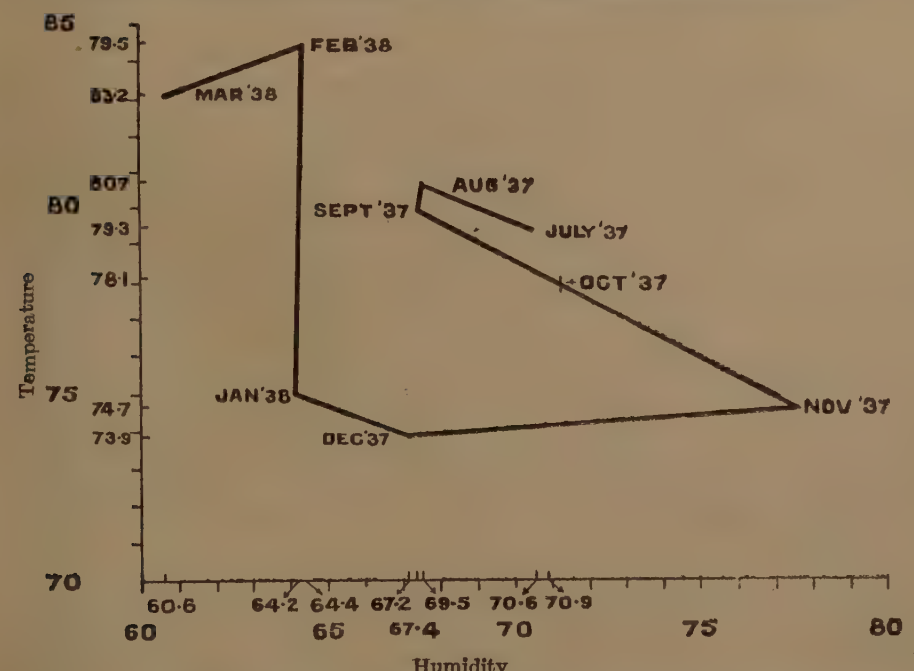

FIG. 3. Temperature and humidity curve, 1937-38 (average mean)

Oviposition

When ready to oviposit the female was seen to spend considerable time wandering slowly over the loaded stalk continuously testing it with its antennae, legs and tip of ovipositor. The antennae are seen directed forwards and downwards and are kept in constant vibration all the time. The parasite not infrequently strays away from the stalk only to return sooner or later to explore the same. After such scrutiny and apparently locating a mobile host grub inside the stem, the abdomen is lowered and the ovipositor is thrust through the bark or through the artificial slit in the stem and the same is driven deep to its entire length. Apparently an egg was laid and the parasite usually wandered away from the spot and no attempt at laying a second egg on the same spot was normally observed. The process of oviposition occupied only a few minutes. Generally oviposition takes place during the day and occasionally during nights. In captivity the parasites deposited normally one egg per host save in a solitary instance when two were placed in the same cell. The maximum per day also did not exceed this number.

Egg-laying period

The duration of the egg-laying period averaged 7·6 days with a maximum of sixteen days for six individuals observed. Oviposition was very irregular and at varying intervals extending up to a maximum of seven days. There was always a distinct post-oviposition period as may be seen from the data gathered. This period ranged from two to twenty-nine days averaging 12·3 days for six observed cases.

Condition of host and position of egg

While playing the part of a primary parasite, the host selected for oviposition was invariably a medium-sized or a full-grown *Pempheres* grub. In a series of trials with other stages, such as prepupae and pupae, no oviposition took place. In the case of *Hypolixus* host, the earlier instar grubs were seen to be preferred in nature. The size of the host apparently forms an important criterion in its choice. The host grubs are seldom noted to be completely paralysed. In almost all cases the host was rendered only partially inactive by stinging, and in consequence the egg deposited may often be found dislodged in the host tunnel. Normally the eggs are placed loosely without any sort of attachment on any part of the host body. Not infrequently these are found deposited in the host tunnel amid excreta and frass. In such cases the larva on hatching moves about quickly in search of the host which it may or may not encounter in the vicinity. A small proportion of host stages was merely partially paralysed without any deposition of eggs. As many as thirty-four stages were rendered partially inactive by a lot of ten females unaccompanied by actual oviposition. It works up to an average of 3·3 stages per female.

Egg (*Plate XXXV, fig. 2*).—The dimensions of the egg vary greatly in accordance with the size of the ovipositing adult. It varies in length from 0·40 mm. to 0·47 mm. averaging 0·45 mm. for five eggs and in width from 0·11 mm. to 0·275 mm. averaging 0·18 mm. The eggs are white in colour with a shining, smooth, polished surface. They are stalked and ellipsoidal in

form with two processes at the poles—a large tubular hollow pedicel at cephalic end measuring 0·35 mm., i.e. approximately two-thirds of the length of the egg and a thin hair like flagellum often irregularly bent or twisted at the caudal end measuring 0·18 mm. roughly equal to the width of the egg. The pedicel is usually folded back along the sides of the egg but may be bent or twisted slightly in various ways.

Incubation

The incubation period ranged from a minimum of one day to a maximum of two days averaging thirty-nine hours for ten eggs during the season July to November 1937. There occurs no appreciable change in colour before hatching except that the thin chorion shrinks to some extent. Prior to hatching the dark brown curved sharp mandibles of the embryo work at the cephalic end near the base of the pedicel. In about ten minutes a breach is effected in the chorion through which the larval head is protruded. The larva emerges slowly taking about forty-five minutes to one hour for completing the process.

Immature stages

1st stage larva (*Plate XXXV, fig. 3*).—The newly hatched larva is translucent white and somewhat flattened and spindle shaped. It is widest in the middle, tapering acutely at the abdominal tip. The head has a slight tinge of yellow and is more chitinised. It is convex in shape and bluntly pointed anteriorly. It bears a pair of minute distinct antenae. The mandibles are dark brown, sickle shaped and strong. Length varies from 0·51 mm. to 0·76 mm. averaging 0·62 mm. for five individuals; the width varies from 0·15 mm. to 0·33 mm. averaging 0·22 mm.; the width of the head averages 0·19 mm. The head is followed by thirteen well-delineated segments with long sensory hairs. The latter are arranged in two rows—dorso-lateral and lateral rows on either side of the median line. The hairs, particularly the lateral ones, on the first two segments are the longest, being nearly $2\frac{1}{2}$ times as long as the rest. The primary larvae are often hatched at a distance from hosts and have to wander about in their search. Not infrequently the host grub itself being only partially paralysed may have migrated in the stem to a distance. In spite of the active search, some larvae might fail to reach the host and perish. The moment it approaches a host, it takes a strong hold on the cuticle by its sharp curved mandibles and begins to imbibe food by energetic suction. The host grub wriggles violently and tries to dislodge the parasite but the latter persists in clinging to its hold. In a few moments the host is rendered helpless and passive, probably by the injection of a toxin by the bite of the parasite. The parasite continues feeding vigorously and the stomach is seen coloured by its contents. The first moult of the larva has been observed in a few cases and takes place within about sixteen hours after hatching.

2nd stage larva.—The larva is glassy white in this stage except for the cream-coloured stomach. It is less flattened and more rounded in form save at the head. The sensorial hairs are much shorter and less conspicuous. These hairs are all of equal length. Average length 1·10 mm.; average width 0·41 mm. and head 0·26 mm.

3rd stage larva.—This stage is more or less similar to the previous one except in size. The mandibles are straight and pointed. Average length 1·65 mm., average width 0·50 mm. and head 0·30 mm.

4th stage larva.—The general aspect is seen to be slightly changed at this stage. The head has become more chitinised and brownish. The mandibles have approximately become triangular. The body is shorter and has become dirty white in colour. It is less active and makes wriggling movements anchored on its head. Average length 2·3 mm., average width 0·65 mm. and head 0·40 mm.

5th stage or full-grown larva (*Plate XXXV, fig. 4*).—This stage is distinctly different in form and colour from the preceding ones.

Length varied from 3·52 mm. to 4·75 mm. averaging 4·03 mm.

Width varied from 0·90 mm. to 1·43 mm. averaging 1·22 mm.

Head varied from 0·42 mm. to 0·74 mm. averaging 0·53 mm. for four larvae.

The general colour has turned to dirty grey. The form has become more rounded and stout in the middle with tapering extremities. Head (Plate XXXV, fig. 5) is convex and short having a pair of cylindrical unjointed antennae and four long setae. The mandibles are dark brown, heavily chitinised and triangular with upper and lower articular processes. The labrum is heavily chitinised in the centre and is coloured dark brown bearing four to seven teeth-like denticles on its ventral aspect. The maxillae are transparent and inconspicuous bearing a pair of tubercles representing maxillary palps. The labium is also thin and possesses a pair of palp-like projections. The body segmentations are distinct having seven longitudinal rows of long setae along dorsal and lateral aspects. Two of these rows are incomplete and extend only till sixth segment. The spiracles numbering nine are open and clear at this stage. The larva, in general, is dull and sluggish.

Larval life after hatching.—The newly hatched larva makes rapid movements in a looping manner by using its mandibles and abdominal tip. It often stands anchored on its head with the rest of the body being raised and swayed in the air in a circle. In about two days the host-grub is killed. By the time it gets full grown nothing remains of the host except its hard head capsule and empty collapsed cuticle. It moves away from the host-remains and enters the prepupal stage. Never more than one adult developed from a single host even though two or more eggs or larvae were artificially left on the same host The developing adults from ill-fed larvae are all under-sized and seldom oviposit. The larval period varied from five to fourteen days averaging 8·3 days for nine individuals.

Prepupa.—The full-grown larva, after voiding the meconium in the form of a small heap of brownish pellets at the caudal end, enters the prepupal stage. The prepupa is ivory white in colour and is contracted very much in size. The size varied within a wide range but averaged 3·6 mm. in length and 1·30 mm. in width for four individuals. It is capable of slight movements when disturbed. It is seen slightly wrinkled and folded in the thoracic region. The duration of this stage varied from one to three days averaging two days for eleven individuals after the discharge of the last meconial pellet.

Pupa (*Plate XXXV, fig. 6*).—The newly formed pupa is yellowish white. It becomes light brown on the second day and turns deep leathery brown in about two days. Soon after, the eyes and antennae become darkened and still later the entire head and thorax turn dark. Gradually the rest of the body also assumes this colour. It is in shape slightly convex on the dorsal surface with the head slightly broader than the body. The size varied greatly but averaged 3·27 mm. in length and 1·1 mm. in width for four individuals. The duration of the pupal period varied from six to twenty days averaging 10·4 days for ten individuals during the season July 1937 to March 1938.

Emergence of the adult.—The pupal covering of the head region breaks transversely at the neck region and the same is pushed forward as a cap to begin with. The rest of the pupal skin splits along the sides from the thorax as far as the middle of the abdomen, dividing it into dorsal and ventral halves. The shining bluish dark adult emerges by pushing itself forward leaving the empty pupal skin behind. The entire process of emergence occupies about twenty to thirty minutes. Ultimately it emerges from the host tunnel to the outer world by gnawing a minute aperture through the bark.

Life-cycle and seasonal history

Since July 1937 when it was first discovered as a parasite of *Pempheres*, laboratory rearings have been conducted till the end of the year. The species has been again met with in February-March 1938 in small numbers in the seasonal crop. Full details on the duration of the total life-cycle periods of a few are furnished in the following table. Data on the rearings of other specimens have been omitted since the records are incomplete in some respects.

Incubation period (days)	Larval period (days)	Prepupal period (days)	Pupal period (days)	Total life-cycle (days)	Sex
2	7	1	7	17	Female
2	5	1	11	19	,,
2	9	3	9	23	,,
1	8	1	11	21	,,
1½	8	2	12	23½	,,

The total life-cycle period got prolonged from seventeen days in July to 23½ days in November and averaged 20·7 days during the period for five individuals. With the approach of the cold season when the temperature goes down accompanied by a comparative rise in humidity, the duration of the developmental instars is found to be prolonged. The duration of the life-cycle period was found to be shortened to some extent (occupying roughly 16½ days) when the species functioned as a secondary parasite on Eulophid pupa. As a primary parasite on the other host, *Hypolixus* grubs, the life-cycle covered

roughly 17½ days. The life-cycle period is seen to be still further shortened when it parasitises *Hypolixus* eggs. Roughly it is seen to cover fourteen to fifteen days with one or two days as egg, five or six days as larva and six to seven days as prepupa and pupa. Even though the data available are admittedly meagre it may be concluded that the period shows appreciable variation not only with the season but also according to the nature of the hosts on which the parasites develop. Considering the period occupied by the host for completing one generation, it may be evident that the parasite can easily have two to three generations for one of the host. Further, since the host generations are uneven and overlapping, the parasite has chance to breed continuously.

Hyperparasitism

The species is usually a primary parasite and its typical or normal host appears to be *Pempheres* grubs. It has been also noted to parasitise occasionally a few other stem-boring weevils. Its activities are not always an unmixed blessing since it has been also definitely noted to play the part of a secondary at times. On two occasions it has been actually taken as a hyperparasite on larva and pupa of the Eulophid—*Euderus pempheriphila*—which is an ectophagous primary parasite of *Pempheres*. It is not possible to say whether the parasite shows any distinct preference to weevil grubs. There is considerable justification in concluding that the species may assume the role of a secondary probably on occasions when primaries occur in abundance and become easily accessible.

Habits of the adult parasite

McConnell [1918] has recorded that an allied species *E. vesicularis* is fond of feeding on the body fluids of the host from the punctures made during oviposition. The writer, despite continuous and careful observations, has not seen this phenomenon in this species. The habit of stinging and paralysing a number of host grubs unaccompanied by egg deposition lends support to the idea that it attacks these probably for purposes of feeding. This diet, however, is not apparently essential for reproduction of the species. The parasite feeds with considerable relish on sweet liquids or raisin and its longevity is considerably increased by this diet. The parasite is very active though devoid of functional wings. They can run rapidly in cages and can take sudden and long leaps in quick succession. The hind limbs and the general build of the parasite are considerably adapted for easy performance of this function. The species is distinctly phototropic and always travels by leaps away from the shaded portions of cages.

Longevity

In the course of the breeding trials some data have been secured. The longevity ranged from a minimum of six days to a maximum of forty-seven days averaging 19·7 days for twelve individuals. It may also be seen that their life is considerably prolonged in the cooler months of October, November and December.

Thelyotoky

The reproduction of the species is characterised by thelyotokous parthenogenesis. From field collections the parasite has been recovered in various developmental stages and these have invariably developed into adults of female sex only. Very nearly three generations of the species have been reared in the laboratory without the appearance of a single male. It looks as if males are unknown in the species ; probably they do not exist ; and that reproduction is always thelyotokous. A proportion among the progeny was found to be incapable of oviposition but this may be due to defective nourishment in the early instars.

Thelyotokous reproduction has been noted in a few instances in parasitic Hymenoptera. Vance [1931] found it to be of common occurrence in *Apanteles thompsoni* Lyle. *Dinocampus terminatus* Nees is another Braconid that reproduces in the same manner. A few other species where the phenomenon is common have been recorded. A great majority of such species belong to Chalcidoidea. Among these may be mentioned *Thripoctenus russelli* Crawford—an internal parasite of thrips, *Achrysopophagus modestus* Timberlake, *Coccophagus modestus* Silv., an Aphid parasite *Aphelinus jucundus* Gahan and the allied species *Eupelmella vesicularis* Retz. a parasite of the Hessian fly. A few, namely, *Hemiteles longicauda* Thoms, *Hemiteles tenellus* Say, *Nemeritis canescens* Gravenh, come under Ichneumonidae. Doner [1936] has recorded two species of parasites of *Coleophora pruniella* which are thelyotokous, namely *Hemiteles tenellus* and *Eupelmella vesicularis*.

Apparently this method of reproduction is of considerable advantage to the species for its rapid multiplication. Reproduction has not got to depend on chances of mating with males. The entire progeny being females, the species has the potentiality of a rapid increase in numbers within a few generations. So far as the present brief studies go, this species has not been observed to be much affected by the apparent advantages of thelyotoky. There has been no great rapidity in its multiplication, very probably brought about by defective nourishment in the feeding instars in rearings in captivity.

Economic importance

The evaluation of the action of a parasite is extremely difficult and requires a great deal of careful and prolonged investigation. The parasite has been encountered only quite recently and its economic possibilities have not been sufficiently explored. These have not occurred in such numbers in the fields as to be of any great significance in the control of the pest. It is a primary parasite which can multiply by thelyotoky. It destroys more hosts than actually oviposited upon. These qualities certainly make for efficiency. On the other hand, their poor rate of oviposition, comparatively prolonged life-cycle period in certain seasons and tendency to play the role of a hyperparasite greatly detract from its economic value. The parasite, however, is of considerable scientific importance because of its unique distribution and polyphagous instincts.

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* Not seen in the original

THE ANATOMY, LIFE AND SEASONAL HISTORIES OF STRIPED MOTH-BORERS OF SUGARCANE IN NORTH BIHAR AND WEST UNITED PROVINCES

BY

B. D. GUPTA, M.Sc., Assoc. I. A. R. I.

Cane Entomologist, Sugarcane Research Station, Muzaffarnagar, United Provinces

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(With Plates XXXVI and XXXVII and five text-figures)

Introduction

A GOOD deal of confusion prevails in the identification of moth borers of sugarcane, viz. :—

1. *Argyria sticticraspis* Hmpsn.
2. *Diatraea auricilia* Ddgn.
3. *Diatraea venosata* Wlk.
4. *Chilo zonellus* Swinh.

The larvæ, pupæ and moths are so similar in their general colouration that it becomes difficult to say which is which. The larvæ possess four to five violet stripes with dark grey tubercles studded over them. These tubercles change their colour due to seasonal and sexual dimorphism which makes their identification still more difficult. For this reason it is desirable to have full descriptions of adults, pupæ and larvæ along with their habits and life histories which will render the identification easier. The description of *Argyria tumidicostalis* Hmpsn., the striped borer of Bengal, has been left out as the author did not come across this borer either in North Bihar or in West United Provinces.

Historical

Mukerji [1857] described the borer as '*dhosah*' from Bengal. Cotes [1889] named it *Diatraea saccharalis* Fabr. Hampson [1898] merged it erroneously with the sorghum borer which he determined as *Chilo simplex* Butler. It was Maxwell Lefroy [1906] who indicated that the said species was different from *Chilo simplex* and named it as *Diatraea auricilia* Ddgn. He asserted that *Diatraea saccharalis* Fabr. did not occur in India. Its true position was brought to light in 1926 when T. Bainbrigge Fletcher compared the Indian species of *Diatraea auricilia* (*Proceeding III Ent. Meeting*, Vol. I, p. 387, pl. 48 and 49, fig. 1) with Dudgeon's *Diatraea auricilia* in the British Museum and established that it was *Argyria sticticraspis* Hmpsn. At the same time the name *Chilo simplex* Butler was discarded in favour of *Chilo zonellus* Swinh. This information indicates that the moth borer sketched by Cotes [1889] in *Indian Museum Notes* Vol. 1, No. 1, pl. 2, figs. 2 (a & b) and named as *Diatraea saccharalis* Fabr. was really *Argyria sticticraspis* Hmpsn.

In some of the recent publications the generic name of *sticticraspis* Hmpsn. has been changed from *Argyria* to *Diatræa*. The matter was enquired from the Imperial Institute of Entomology, London. Sir Guy A. K. Marshall's remarks of 28 July 1938 on the present position of *Argyria* are quoted :—

> ' In the British Museum collection this insect stands under the genus *Argyria*, but there is a note added to the series to the effect that the species really belongs to the genus *Diatraea*. This note was put in the collection by Mr T. Bainbrigge Fletcher, and it is as a result of this note that we have sent out the species under *Diatraea*. I have now consulted Mr Tams on the subject and he informs me that he does not agree with Mr Fletcher's opinion. Unfortunately the genus *Argyria* as constituted by Hampson is in very great confusion, and an extensive revision will be necessary before the species which really belong to it can be ascertained. For the present, however, Mr Tams suggests that *sticticraspis* should be retained in the genus *Argyria*'.

Occurrence and distribution

Argyria sticticraspis Hmpsn. occurs in sugarcane during the hot weather of April, May and June when the crop is young. Its activity goes down with the breaking of monsoon rains. The borer is fond of shoots and has not been observed to do severe damage to cane stalks in these parts. *Diatraea auricilia* Ddgn. and *Diatraea venosata* Wlk. attack the grown-up canes during rains and continue their ravages till hibernation sets in in November. *Chilo zonellus* Swinh. is not really a pest of sugarcane. It has been found to occur in only those cane fields which are in the neighbourhood of borer-infested fields of maize (*Zea Mays*) or *juar* (*Andropogon sorghum*). In all these cases the borer injury can be detected by the drying up of the central leaf sheath commonly known as ' dead heart '.

Cultivators do not differentiate between different species of borers but designate them according to their colour, habits or the effects they produce on the crop. They are locally known as *goruan* in the Punjab, *dhosah* and *majera* in Bengal, *phankala*, *kansua* and *pihka* in the United Provinces. These names in the languages of the provinces indicate that some of these borer species are present practically all over the sugarcane tract of northern India.

Morphology

(1) *Argyria sticticraspis* Hmpsn.

Adult

Female—Wing expanse 23 to 35 mm., colouration of female as given by Hampson [1919] is noted below :—

> ' Head and thorax greyish ochraceous suffused with red brown ; palpi irrorated with dark-brown ; abdomen greyish ochreous with rufous at base of dorsum ; pectus, legs and ventral surface of abdomen tinged white with ochreous brown. Fore-wings greyish ochreous suffused with red brown. The cell and area just below and beyond it irrorated with darker red brown ; a curved post medial series

of small red brown spots in the inter-spaces from below costa to vein I ; a terminal series of minute black spots defined on inner side by slight white spots ; cilia with slight red brown lines near base and at middle. Hind wings pure white, underside of fore-wing tinged with rufous.

The females in the author's collection do not exactly agree with the description reproduced above. The post-medial series of brown spots is absent. In the inter-spaces from below costa to A_1 instead of these spots there is an ochreous streak without red-brown. Two dark spots between A_1 and Cu_1 behind the cell, another at the angle of the cell.

Male—Wing expanse from 19 to 26 mm. Head and thorax ochreous red brown ; antennæ ringed black and white, palpi ochreous mixed with dark brown. Tibiæ of 1st thoracic leg greyish ochreous, rest white red brown. Fore-wing pale red brown mixed with whitish and irrorated with blackish along the median nervure. Dark brown scales in front, behind and in the cell in the anterior median area. A black patch in front of the cell defined on outer side with a whitish spot. The area between marginal and submarginal dots dark brown with streaks as in the female. Hind wings ochreous ventrally in front of the cell.

Hampson did not describe the male of *Argyria sticticraspis* but has given the description of male of *Argyria coniarta*, a separate species, of which he did not describe the female. The description given above for the male of *Argyria sticticraspis* agrees with the male of *Argyria coniarta* Hmpsn. The description given by Hampson for the female of *Argyria sticticraspis* does not tally with the description of females in my collection. It thus appears that *Argyria sticticraspis* and *Argyria coniarta* are not two different species but have been separated on individual description of female in the former case and male in the latter of the same species.

Head.—Front convex in either sex. A well-defined epicranial suture between the two antennæ. Length of head shield greater than the breadth. Ocelli on protuberances behind the antennæ. Antennæ lamellate and flat in males and filiform in females. Scape large and swollen, pedical short and rounded, joints of funicle in male increase in width distally and shorten at the tip. Forty-one joints in both sexes. Internally every joint bears two big ciliated scales. Labrum is scaleless.

Thorax.—Patagia paired narrow transeverse plates closely opposed to the anterior end of the thorax. Well developed tegulæ covered with dense hairy scales. Prothoracic sclerite narrow, meso-scutum broad with a longtitudinal suture and meso-scutellum diamond shaped ; meta-scutum narrow in the middle and extended laterally with meta-scutellum extending far behind over the first abdominal segment.

Wing-venation (*Plate XXXVI, fig. 1*).—Fore-wing : (Nomenclature after Comstock and Needham). Sc. well developed, separate and unbranched. R_1 from middle of the cell, R_2 and the stalk of R_3 and R_4 from before the angle of the cell. The stalk longer than either R_3 or R_4. R_5 from apex of the cell. M_1 is discocellular originating from the angle of the cell. Its point of origin nearer to R_5 than M_2. M_2 and M_3 arise from the cell in close proximity but are not fused. The cross vein PTV which closes the cell distally is fine but

prominent. It is curved inward to form an angle which is not sharply defined. The two branches of Cu_1 are present. Cu_2 absent. Cu_1a from before the lower angle of the cell and Cu_1b from the middle of the cell. A_1 is present but A_2 is rudimentary. R_4, R_5, M_1, M_2, M_3, Cu_1a, Cu_1b, and A_1 are equidistant with each other on the margin of the wing.

Hind wing: Sc. + R_1 and Rs. arising free but anastomosing closely beyond the cell to diverge again into Sc. + R_1 and Rs. M_1 from Rs. before its fusion with Sc. + R_1. The cross vein PTV is finer than that of the fore-wing and angle PTV is less than a right angle. The area of the cell is reduced due to drawing in of the cross-vein towards the base of the wing. M_2 and M_3 in a common stalk from the lower angle of the cell and diverge later into M_2 and M_3. Cu_1a from near the angle of the cell and Cu_1b from the middle of the cell. A_1, A_2, A_3 present. Frenulum consists of a single stout spine in males and of four spines in females.

Legs.—A pair of spurs on tibia of the first and second, and two pairs of spurs on the tibia of the third pairs of legs. Each leg has five tarsi, every joint of which bears a pair of spines. Claw is composed of paired ungus with pulvillus between. Ungus notched to give rise to a pair of spines.

Abdomen.—First abdominal segment is reduced being merged with that of meta-thorax ; sternum of second abdominal segment bears a pair of tympana. Segments 9th and 10th are modified to form genitalia in both the sexes.

Female genitalia (terminology after Busck and Heinrich).—Internal: They consist of ovaries, oviduct, collateral and accessory glands, their ducts and sperm-ducts. The ovaries consist of four ovarioles on each side extending from first to sixth abdominal segments. They are much convoluted in their course and fill the whole of the abdomen in freshly emerged specimens. Oviduct is formed by the two groups of four ovarioles from each side to open on the ovipositer. Collateral gland is of a small size and communicates with the oviduct. Below, the oviduct receives the sperm-duct from ductus bursæ. The sperm-duct joins the oviduct on the ventral surface near the junction of the collateral gland. Receptacula seminalis lies above the angle of the junction of ovarioles. A pair of accessory glands milk-white in colour and full of chalky material open into the oviduct in the ninth abdominal segment. The two glands communicate with each other below the rectum.

External : Ovipositor is a chitinous oval ring profusely studded with setæ and bristles. The ring is supported by chitinous stylets. The genital opening or the opening of bursa copulatrixlies on the ventral surface of the eighth abdominal segment on a heavily chitinised plate. Bursa copulatrix is provided with a star-shaped crystal—the signum.

Male genitalia.—Internal : Testes are in the form of a single dorso-ventrally flattened, round disc of a light yellowish green colour. Two vasa-deferentia (v. d.) arise posteriorly and after a short distance enlarge into two pearl-shaped pouches—the vesicula seminalis (v. s.) afterwards getting narrower to open into the accessory glands. The latter are paired tubes closely approximated together and are full of chalk-like material. They get considerably prolonged anteriorly in a thread-like form. Posteriorly they unite to form the ejaculatory duct which opens on the adeagus after a much convoluted course.

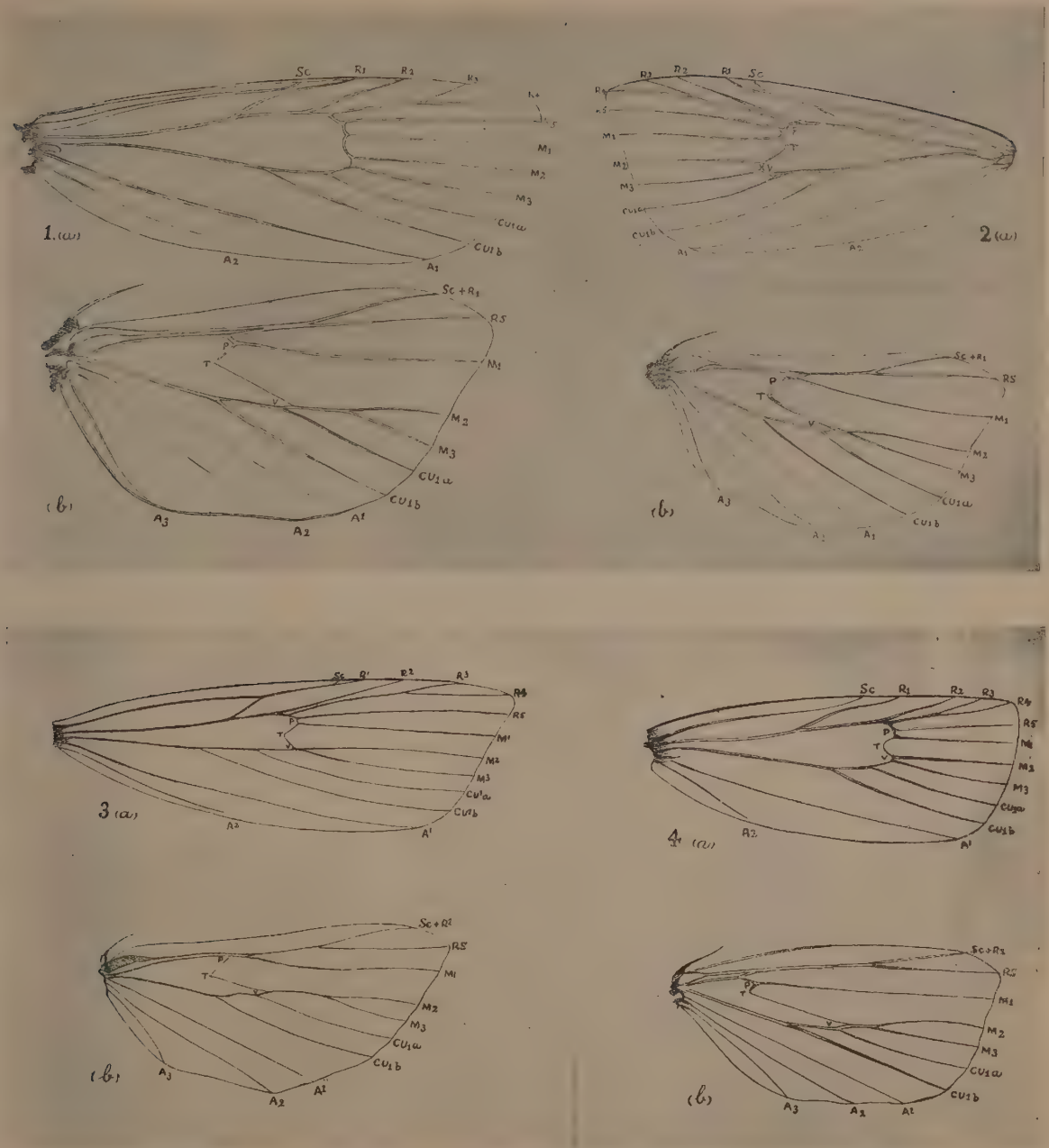

FIG. 1 (*a*) & (*b*) Wing-venation of *Argyria sticticraspis*
FIG. 2 (*a*) & (*b*) ,, ,, of *Diatraea auricilia*
FIG. 3 (*a*) & (*b*) ,, ,, of *Diatraea venosata*
FIG. 4 (*a*) & (*b*) ,, ,, of *Chilo zonellus*

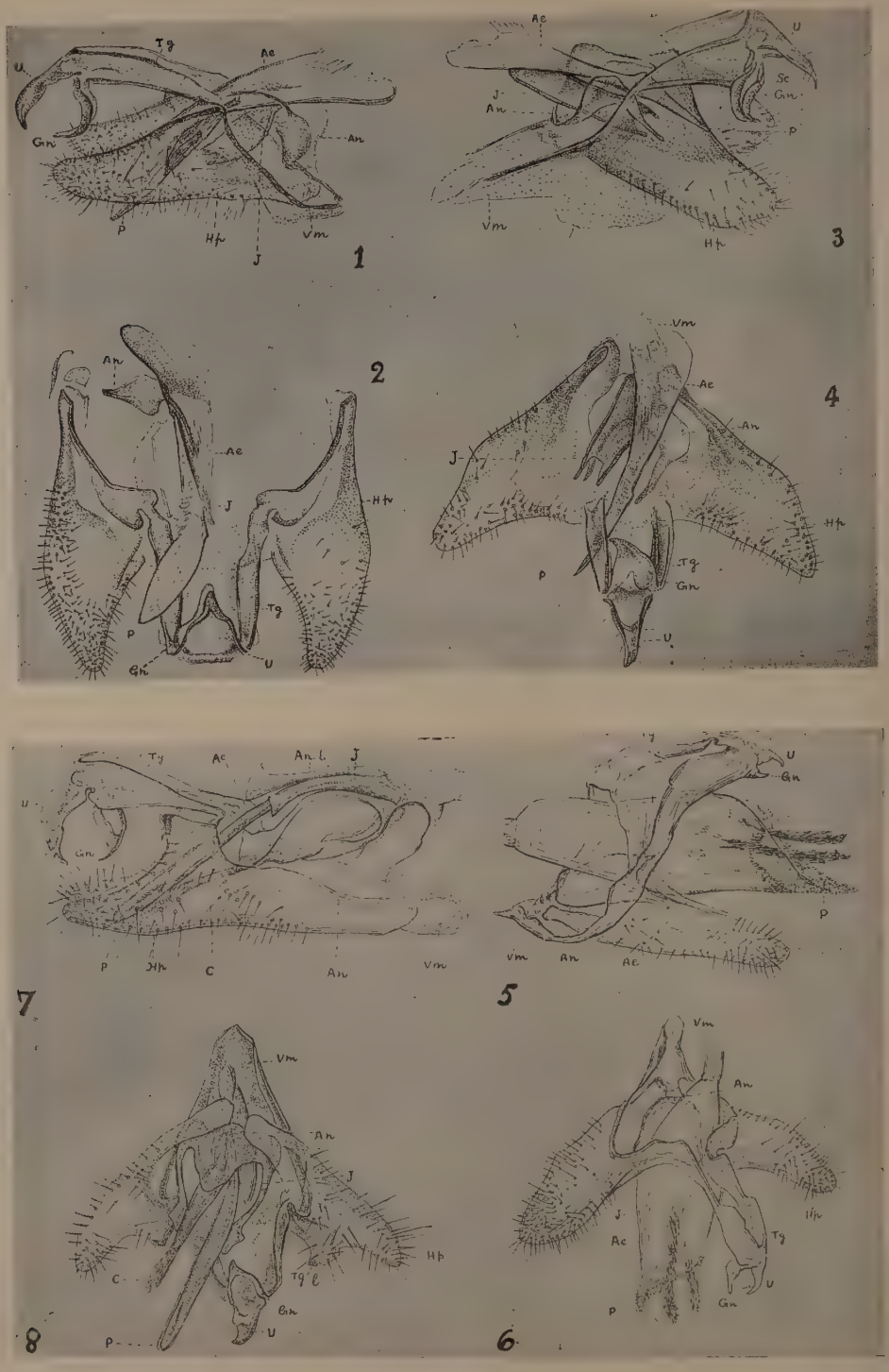

FIG. 1 & 2. External male genitalia of *Argyria sticticraspis*
FIG. 3 & 4. ,, ,, ,, of *Diatraea auricilia*
FIG. 5 & 6. ,, ,, ,, of *Diatraea venosata*
FIG. 7 & 8. ,, ,, ,, of *Chilo zonellus*

External (Plate, XXXVII, figs. 1 & 2): Vinculum (vm) flat, heavily chitinised and enlarged ventrally. Anellus surrounds the adeagus partially. Juxta bilobed and closely applied to adeagus ventrally. It is canaliculus. Adeagus slightly bent with blind sac produced posteriorly beyond the entrance of ductus ejaculatorious. Penis curved and sword shaped with cornutii present. Harpes hinged within the vinculum, simple wing-like, triangular and divided but without any basal lobes. Tegumen broad at the place of articulation with gnathos. Uncus single, massive and triangular. Gnathos hook-like forming achæla with uncus.

Pupa

Elongated, slender from deep to dark brown in colour, measuring approximately 13 mm. in males and 17 mm. in females. The integument is transparent in newly formed pupæ and development of the imago can be observed.

Head.—Pair of frontal setæ on fronto-clypeal region which is flat ventrally. Pilifers and maxillary palpi present. Eyes promixally sculptured and distally glazed ; large in males than in females. Labrum well differentiated with a prominent notch. Front laterally extended into projections over the eyes.

Thorax.—Mid-dorsal ridge extending from prothoracic to meta-thoracic terga. Pronotum narrow and rough with a spine on each side of the ridge. Mesonotum very wide ; mesoscutellum not differentiated. Wings extend beyond the ventral half of the fourth abdominal segment. Wing suture is not defined on the mesonotum. Anteriorly the margin is raised in the form of a semi-lunar curve which possesses a metallic lustre. Mesothoracic legs do not reach the ventral margin of the wings. Meta-thoracic appendages extend beyond the wings.

Abdomen.—First four abdominal segments are free dorsally while hidden below by the integument of the wings. A pair of setæ of the anterior trapezoid warts persist on all the abdominal segments as short brown spines. First pair of abdominal spiracles absent; present on second to seventh abdominal segments on raised projections. Eighth abdominal spiracle atrophied but its situation visible. Ventrally the impression of the prolegs is left on the fifth and sixth abdominal segments. Dorsal surface of fifth, sixth and seventh segments bear ridges. They lie in the anterior half of each segment between the lateral spiracles of the two sides. They encircle the seventh abdominal segment and their sharp projections are directed backward. The dorsal half of the tenth abdominal segment possesses four spines directed towards the posterior.

Genital openings.—The male genital opening lies on the sternum of the ninth abdominal segment. It is in the form of a fine slit lying between two raised projections. The female genital opening lies ventrally on the eighth abdominal segment in the form of a narrow longitudinal dark brown slit.

Larva

Full-grown larvæ measure 20 to 25 mm. in length and 4 mm. in breadth, cylindrical in shape with a dark brown head directed towards the anterior. The colour of the body is dirty white with five violet stripes on the dorsal surface. The stripes from second thoracic to eighth abdominal segment are arranged in the following manner (Fig. 1).

(1) Single dorsal stripe.
(2) The two sub-dorsals—one on each side of the dorsal stripe.
(3) The two laterals—one on each side of the sub-dorsals.

FIG. 1. Side and dorsal view of *Argyria stictioraspis* Hmpsn.

The dorsal stripe is central and unpaired and originates from the anterior border of the first abdominal segment and extends up to the tubercles on the eighth abdominal segment and often beyond it. It is straight and narrow and sometimes cannot be made out due to the brown colour of the alimentary canal lying below.

The sub-dorsals and lateral stripes originate from the meta-thoracic segment and join each other to encircle the eighth abdominal spiracle. The lateral stripes are supra-spiracular in position.

The body-wall is formed of transparent chitin studded over with dark grey tubercles bearing dark brown prominent setæ. The grey colour of the tubercles disappears in some of the mature larvæ before July and in all after July. With colourless tubercles and deep violet stripes the larvæ pass on to hibernate in winter.

Spiracles are oval in outline having a jet black rim with a clear space within. They are in nine pairs, viz. one on each side of first thoracic and others on the first to eighth abdominal segments. The last is the largest and more dorsally placed. The opening is guarded by several rows of filaments gradually increasing in size towards the interior. These ribbon-like filaments are provided with minute fibrillæ.

Larval details and chaetotaxy

The head is deep brown in colour becoming darker anteriorly. It is spherical in outline bulging in the posterior region and getting trapezoidal and dorso-ventrally flattened anteriorly which brings the mouth-parts on a level with the ground.

Head capsule.—Each epicranial plate bears six ocelli, four of which lie in an arc on the lateral margin while two are more ventrally situated. First ocellus is the largest while the third and fourth are smaller than others and lie approximated.

There are thirteen setæ and eight punctures besides the ultra-posterior group of setæ and punctures. Dyar and Heinrich [1927] nomenclature for setæ and punctures has been followed.

The anterior setæ A_1, A_2 and A_3 do not form exactly a right angle as they do in *Diatraea saccharalis* as described by Halloway and Loftin [1919], but lie

in an angle greater than a right angle. The distance between A_1 and A_2 is less than A_2 and A_3. Puncture Aa posterior to A_2 and in a line with A_1 and A_2. Posterior setæ P_1 and P_2 and puncture Pa parallel with the longitudinal ridge LR. P_1 in a line with adfrontal seta Adf_1 and Pa with the puncture Adfa, P_2 more approximated to Pa than P_1.

Ocellar setæ O_1, O_2 and O_3 are well separated. O_1 lies below and between the III and IV ocelli and is shortest of the group. O_2 biggest and nearer to ocellus I than VI. O_3 latero-posterad of ocellus VI with puncture Oa between ; Oa more approximated to ocellus VI than O_3. Punctures Ob and Oc lie anterior and approximated to ocelli IV and V respectively.

Sub-ocellar setæ So_1, So_2 and So_3 are situated ventrally in a triangular formation. So_1 in the ventral angle behind the antenna. So_2 approximated to ocelli V and VI. So_3 far removed, with puncture Soa between So_2 and So_3.

Lateral seta L_1 on the gena in a line with P_1. Puncture Pb between L_1 and P_1 but more approximated to L_1. Puncture La posterior to seta L_1. Genal puncture Ga and seta G_1 on ventral aspect in a line with cardo. The group of ultra-posterior setæ and puncture (x) lie posteriorly very much approximated to each other.

Frontal puncture Fa almost touching each other with frontal seta F_1 far behind situated latero-posteriorly. The frontal punctures are well separated in *Diatraea saccharalis*.

Adfrontal sclerites bear two minute setae and one puncture on each side. Distance between frontal seta F_1 to adfrontal seta Adf_1 is more than the distance between Adf_1 and Adf_2. Seta Adf_2 lies in the angle made by the adfrontal suture with the longitudinal ridge ; puncture Adfa nearer to Adf_2 than Adf_1. Cylpeus carries a pair of setæ E_1 and E_2 on each side. The third segment of antenna bears a shaft, a puncture, two spines and two sensory cones along with the articulation of fourth joint which carries one sensory cone of its own.

Mouth-parts.—Labrum : An unpaired oblong and flat sclerite with a little convexity in the central region, wider than high, free edges rounded and a notch in front. Two groups of setæ on each side of the notch. Median setæ M_1, M_2 and M_3 triangularly arranged. M_2 posterio-lateral and closer to M_1 than to M_3 which lies far in front. Lateral setæ, La_1, La_2 and La_3, lie in a curve one behind the other on the lateral margin. La_2 and M_3 on the same level. La_1, La_2 and La_3 equidistant with each other. Setæ La_2 longest of the group. Puncture Ma posterio-lateral to M_2 and lies behind in a line with M_1.

Epipharyngeal shield is closely applied to labrum above and possesses two sets of sensory cones. The first set ET lies in a triangular formation in the space below and between the median and lateral groups of setæ of the labrum. The other set consists of four sensory papillæ EP lying in a rectangular formation—two in front and two behind the seta M_2. Epipharyngeal rods are indicated by the posterior projections.

Mandibles : Each mandible bears six protuberances in the form of teeth—two of which are conical while others have a spherical or pointed appearance. Each mandible bears one small (*i*) and one large (*ii*) seta.

Labium : Ring shaped composed of three sclerites. First bears a pair of labial setæ, second forms a semi-circle at the base of the palp and carries three

pairs of punctures, two on each side of labial setæ and one on each side of the spinning tube. The third piece forms the spinnerat.

Maxillae : The maxillae are fused with the labium at the base but are free at the tip. Cardo forms the base. It is heavily chitinised and glove-shaped. Stipes bears two chitinised rings of the palpus having a spine on each with two lobes at the top. One is the maxillary palp and is two-jointed. The other is the maxilla proper ending in small sensory cones.

Mentum is triangular and lightly chitinised. It bears a pair of prominent setæ directed downwards and forwards. The paired sclerites lying one on each side of the mentum bounded by a part of stipes and cardo laterally constitute the submentum. It is formed by two triangular sclerites which are lightly chitinised and run with each other up to the posterior limits of the cardo.

Thorax.—Prothoracic shield covers dorsally the major portion of the first thoracic segment. It is broad and divided into two equal halves by a mid-dorsal longitudinal fissure. It is generally brown but gets dark on the approach of a moult and gets yellow when tubercles become colourless. Black pigment spots are present all over but they are more concentrated on the posterior border of the shield. It has seven setæ and three punctures named after Fracker [1915] on each half of the shield.

Anterior margin has three setæ Ia, Ib and Ic directed upwards and forward. Punctures X and Y adjacent to seta Ia and puncture Z approximate to Ib. The other group of setæ IIa, IIb and IIc are centrally placed. The posterior seta P is inconspicuous lying on the posterior periphery of the shield.

Sub-spiracular tubercle is formed by the fusion of the tubercles IV and V each having one seta. VI is bisetose, VII multisetose forming the base of the leg, VIII is unisetose and lies beyond the leg on the ventral surface. The segment is devoid of III tubercle.

Meso-and meta-thorax resemble each other in their arrangement of the setæ and punctures. Central dorsal tubercle CDT is bigger on the former than on the latter and corresponds with the prothoracic shield of the first thoracic segment. The two are devoid of setæ but possess brown pigment spots.

Ia and Ib of prothoracic shield form a separate tubercle lying anterio-lateral of CDT, similarly setæ IIa and IIb lie on a separate tubercle. III is unisetose, IV, V, VI, VII and VIII as on prothorax. Sometimes a small tubercle Va is present. When present it is often repeated on first four abdominal segments. Extra setæ Ixa, Ixb and Ixc lie in front of the leg on the ventral surface. The small tubercle Xa with a single seta lies on the anterior border in front of tubercle Ia and IIb. Bisetose tubercle Xcd is peculiar to these two segments and is not repeated on any other.

Thoracic leg.—Base is formed by VII tubercle with three prominent setæ in front, one behind and three facing the mid-ventral line. Leg has four segments. First has two setæ and two punctures second has a set of five to six spines, third has one dorsal and one ventral setæ while the fourth ends in a hooked claw.

Abdomen.—The tubercles Ia and Ib, IIa and IIb have become unisetose and lie one behind the other. Thus the four unisetose tubercles of the two sides lie in a trapezoid formation and are known as trapezoid tubercles. The bases of the setæ of the trapezoid tubercles lie at an angle of 50°. Anterior

trapezoid tubercles are spherical while the posterior ones are oval in outline. Two to three pigment spots are present anterior to seta I which is bigger than the seta II of the post-trapezoids. This trapezoidal arrangement is constant up to seventh abdominal segment. Often central dorsal tubercle CDT in-between the posterior trapezoid fuses with the latter on both sides. III is unisetose and supra-spiracular in position with a minute seta IIIa in proximity. In the segments following the first abdominal segment it gets separated from III and lies anterior to spiracle but fuses with III tubercle again on the eighth abdominal segment. IV and V are sub-spiracular and persist up to ninth abdominal segment. VI is unisetose throughout. VII is trisetose from first to sixth abdominal segments forming the leg plate on third, fourth, fifth and sixth abdominal segments, bisetose on seventh and unisetose afterwards. The only change that happens on the eighth abdominal segment is the fusion of the trapezoid tubercles. Tubercle I disappears on the ninth abdominal segment. III, IV and V fuse to form a bisetose tubercle. Tenth abdominal segment has an anal plate with four long setæ in each half. Pigment spots are present. Base of the clasper has eight setæ and one puncture. Ventral tubercle VIII is constant throughout.

Pseudo-leg.—It is a fleshy conical and retractile projection with round and flat apex directed towards the posterior. The sole is provided with a series of hooks called crochets. The hooks number about forty in adult caterpillars and are biordinal in arrangement. The spines are embedded in such a way that both the ends are free. They lie in a horse-shoe formation and open towards the exterior. The claspers on tenth abdominal segment are provided with crochets arranged in a semi-lunar curve.

THE EGG

The eggs are oval, dorso-ventrally flattened and are laid in clusters in three to five overlapping rows. Freshly laid eggs are transparent but become creamy white a few hours after deposition. An individual egg measures from 0·7 to 0·9 mm. in length and 0·65 mm. in breadth. All the eggs in an egg mass are of the same size and shape. The longitudinal axis is always parallel with the mid-rib of the leaf. They are firmly glued onto the surface of the leaf. The chorion is transparent, colourless and under a microscope reveals a beautiful ornamentation in the form of an irregular net-work of depressed lines. The empty egg-shells are white and more conspicuous and remain attached to the leaf till beaten away by weather.

The eggs are laid in clusters on the under-surface of the green leaf. They have never been seen on dried leaves. The egg-laying takes place at night. A single female laid 366 eggs in one night in eleven egg masses with sixteen to sixty-five eggs in each cluster. The oviposition was again resumed on the night following with five clusters having a total of 123 eggs. The number of eggs in the body is innumerable and dissection of females after egg-laying shows that all the eggs are not laid.

Unfertilized eggs are laid singly in scattered groups of two to three devoid of any symmetry. They quickly shrivel up. An unfertilised egg mass is seldom found in the field.

Development.—The originally homogeneous contents of the egg exhibit three well-defined bands twelve hours after oviposition. The developing larva lies in

the centre in a horse-shoe formation. The disintegration of yolk into small globules can be observed on the second day.

Two eye-spots and brown patches of future mandibles along with body segments appear on the third day. On the fourth day the head and prothorax become clear as dark bands, and tubercles with minute spines can be seen. Feeding on yolk can be marked by the movement of yolk strings towards the mouth where they are torn by the mandibles. Hatching takes place on the fourth to sixth morning at sunrise or at little after. Majority of the larvæ in the egg mass hatch out together. A few may take another twenty-four hours in hatching.

LIFE-HISTORY

Copulation generally occurs at night. A pair remained in copulation for 2½ hours in the laboratory. Eggs are laid a few hours after copulation. Incubation lasts from four to six days. Hatching always occurs at sunrise or a little later. Freshly hatched larvæ measure about 1·5 mm. with black head and prothorax. Body on hatching is dirty grey with faint impression of stripes. The abdominal trapezoid tubercles are present in the form of black dots.

Larvæ are quick and agile with very active spinning glands. They swing in the air by the silken threads and get dispersed to surrounding plants by the help of wind. They are quick in crawling from plant to plant or to the axils of leaves on the same plant. Those which come in contact with central whorl of plant leaves eat their way in and create dead heart. Later in the season when cane has formed they enter by making pin-holes anywhere in the internodes. In western United Province the young larvæ behave as leaf-miners for a few days before penetrating into the plant stalk.

Second instar larvæ.—Larval details get completed. Mid-dorsal stripe becomes continuous and prominent. Pro-legs assume their normal shape and crochets take the horse-shoe formation. Black pigment spots on tulercles are absent at this stage. They appear in the fourth instar. The larvæ get perfectly matured in the fifth instar.

Ecdysis.—When the time of moulting draws near, the caterpillar becomes motionless and stops feeding. The colour of the head and theprothoracic shield becomes black. The skin between the head and prothoracic region gets stretched and ultimately ruptures. By gradual contractions of the body this outer coat of skin is pushed back till it is cast off. The head capsule which is now an outer coat of the head is dashed against the surface and is gradually discarded by the help of the anterior pair of appendages.

Each moult takes about forty-five to sixty minutes. In the final moult the larva changes into a pupa. During the final moult, the head capsule is not cast off separately from the skin but the capsule ruptures along the epicranial suture and is discarded posteriorly along with the skin.

Five moults are common before the caterpillar actually pupates in the active season. The number of moults increases to seven or eight in hibernating larvæ.

The larvæ of *Diatræa saccharalis* eat their cast skins and are cannibalistic in habit as has been observed by Halloway and Loftin [1919]. I have not observed this phenomenon in the case of any of the sugarcane-borer larvæ.

Growth.—All the larvæ hatched from the same egg mass do not grow equally. The growth depends to some extent on the nature of food they come across. The larvæ fed on soft tissues grow more quickly than their fellows feeding on hard material. The larval existence is roundly of sixteen to twenty-one days' duration. Some larvæ take as many as thirty days to pupate. In case the plant succumbs to injuries and dries up, the larvæ, if not old enough, migrate to neighbouring plants and if full grown resort to pupation.

Pupal period.—This period considerably varies between the over-wintering larvæ and the larvæ of the active season. In February the period lasts from ten to twelve days, but in summer it is short and pupation is over within six to eight days, the average for the active season being a week. The progress of various pupal changes is as follows :—

1st day.—Body yellowish brown, stripes dirty-violet, rims of spiracles brown and projected, pro-legs atrophy rudiments of wings and appendages, two dark eye-spots and sexual markings are discernible.

2nd day.—Yellow colour deepens, venation is marked out, eye-spots turn into dark patches.

3rd day.—Compound eyes are differentiated.

5th day.—Pupa dark brown, eyes greenish grey, wing scales differentiated into black and white, gliding and rolling movement of posterior abdominal segments persists.

6th day.—Pupa deep dark brown, no sign of life exhibited.

7th day.—Emergence of chrysalis.

Emergence of adults.—This always occurs in the early hours of the morning generally before sunrise. Anterior extremity of pupa breaks to give exit to the moth. The first rupture is the transverse slit along the posterior border of the front. This piece breaks and hangs down. The second rupture is along the length of thorax in mid-dorsal region. The third slit is lateral and runs along the whole length of antennal suture of each side. During emergence the posterior pairs of legs are the first to be dragged out along with the thorax. In doing so first pair automatically comes out and is followed by the second pair of legs and wings. The latter are short and unexpanded. The body is held on first pair of appendages. After about twenty minutes the wings expand to cover the body and it is then that the 3rd pair of legs is brought to the ground.

Summary of life-cycle

The total period taken from egg-laying to the adult stage in laboratory cages is thirty days in September, viz. egg four to five days, larva twenty-one days and pupa seven days. The period of different instars of the larvæ hatched from the same egg mass is shown in Fig. 2. Twenty-seven days is the shortest period which an individual life-cycle takes from egg-laying to the emergence of adult.

SEASONAL HISTORY

Over-wintering larvæ are stimulated to activity by the last week of February when majority of them pupate. Emergence of moths begins by the beginning of March and continues for the whole of March and egg-laying continues till the middle of April. The adults of the second generation lay their eggs by the middle of May and moths continue to emerge till the end of June. The third

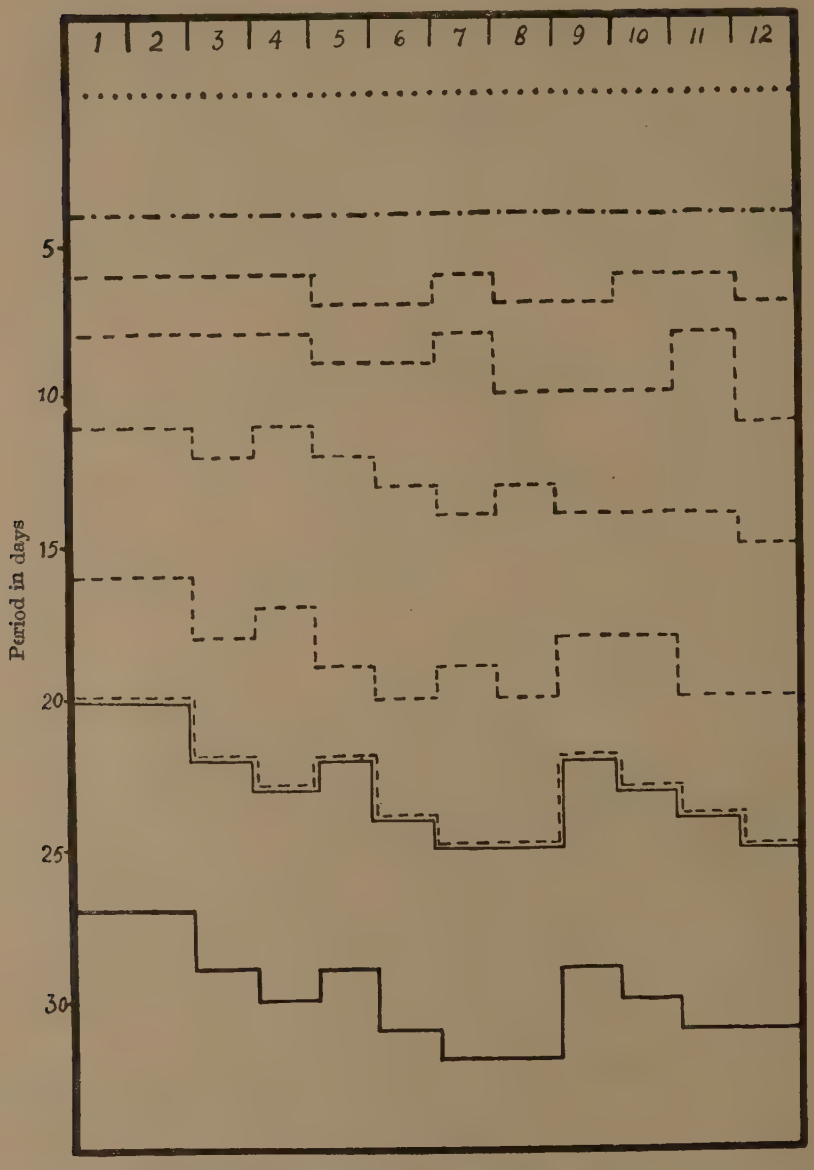

FIG. 2. Relative incubation period, duration of the larval stages and the pupal period of 12 *Argyria sticticraspis* all hatched from the same egg mass in September 1930

[.... Egg-laying; -.-.-. Hatching; – – – Instars; ═══ Pupation; ——— Emergence of chrysalis]

generation continues up to the middle of August and fourth finishes by the end of September. Egg-laying of fifth generation commences by the beginning of October and the larvæ hatched from these eggs hibernate. Thus there are five

to six generations in the year depending upon the early beginning of warm weather during spring and late closing of autumn for winter. This seasonal behaviour of the pest is true for both North Bihar and Western United Provinces.

(2) *Diatraea auricilia* Ddgn.

ADULT

Dudgeon [1905] described the adult from Pusa in the following words :—

'Antennæ of male flattened by coalescing lamellæ separated distinctly.

Males—Brown ochreous, irrorated with fuscous ; a raised metallic spot in the cell, another at the origin of vein 4 and 5, one above and one below vein 2. A few golden scales in and beyond the cell, a post-medial row of black dots incurved towards the costa with golden scales upon them, a marginal row of black dots. Cilia golden. Hind wing brownish white, cilia silvery.

Females—Big, antennæ simple, ground colour pale, ochreous with metallic spots smaller '.

The general colouration of the moth in my collection agrees with the description reproduced above. The maxillary and labial palpi ochreous but suffused with dark brown. Abdomen ochreous suffused with brown at the sides and beneath. Tibiæ of first thoracic appendage ochreous but irrorated with dark. There is a medial row of rufous lying at the distal border of the cell. Five metallic spots with golden scales in a regular curve over the rufous band. The raised metallic spot, as described by Dudgeon, lies at the apex of the cell at the origin of vein 6, i.e. M_1. Another spot along the rufous curve at the origin of R_2, R_3, R_4 and R_5. Ventrally the fore-wing is ochreous suffused with grey. Hind wing from ochreous to dark grey.

Antennæ in females are filiform with alternating grey and ochreous scales. Medial and sub-marginal rufous bands are imperceptible. Metallic spots arranged as in males.

On account of the golden lustre of the metallic spots and those of marginal cilia *Diatraea auricilia* Ddgn. is commonly known as ' Gold-fringed moth of India.' Females possess wing expanse from 22 to 30 mm. while in males it is from 16 to 25 mm.

Head.—Front is conical and protruded beyond the eyes in males, rounded in females. This feature distinguishes it from *Chilo zonellus* because in the latter the front is conical and protruded in both males and females.

Wing-venation (*Plate XXXVI, fig. 2-a*). Fore-wing.—Vein Sc. arises free but fuses with R_1 in front of the cell. Distally the two diverge again into Sc. and R_1. The stalk of R_3 and R_4 is equal to the branch R_4 but bigger than R_3. The veins $R_3 + R_4$, R_5 and M_1, arise at equal distance from each other at the apex of the cell.

Hind wing (Plate XXXVI, fig. 2-b).—Sc. and R_1 arise free but immediately fuse to form a common vein Sc. *plus* R_1, which fuses with Rs near the angle of the cell. After running for a distance they diverge into Sc. *plus* R_1 and Rs. M_1 arises from Rs before it coalesces with $Sc+R_1$ but it originates beyond the upper angle of the cell. PTV is faint but the angle is that of 90°. M_2 and M_3 arise together in a short stalk from the lower angle of the cell.

Female genitalia : Internal.—Accessory glands a little less developed while other structures resemble those of *Argyria sticticraspis* Hmpsn.

External.—Ovipositer and collar as in *Argyria sticticraspis*. Genital opening surrounded by chitinous folds. Chitinous plate absent. Bursa copulatrix and ductus bursæ simple ; signum absent.

Male genitalia : Internal.—Testes dorso-ventrally flattened in the form of a disc. Vasa deferentia are closely approximated at origin, dilated afterwards to form vesicula seminalis. The two tubes fuse to form a single convoluted tube the ejaculatory duct to open at the adeagus. The accessory glands in the form of thin tubes communicating with vesicula seminalis.

External (*Plate XXXVII, figs. 3 and 4*).—Vinculum triangular, grooved and drawn out posteriorly. Anellus an incomplete ring, its lobes extending forward. Adeagus straight and pointed posteriorly. Penis arrow shaped. Cornutii present at the neck of the arrow. Harpes as in *Argyria sticticraspis* but hinged with vinculum. Tegumen short and triangular. Uncus with pointed apex, devoid of hook. Socii in the form of small sclerites, one on each side lying between gnathos and uncus.

PUPA

Disposal of different structures resembles *Argyria sticticraspis*. It differs from the latter in its cranial region which is neither rough nor raised up. A transverse ridge is present above the eye and is protruded like short horns. There is an incomplete circle of distinct spines on the seventh abdominal segment extending beyond the spiracles. The posterior extremity is divisible into dorsal and ventral halves, each possessingtwo pointed projections.

LARVA

The caterpillar very closely resembles that of *Argyria sticticraspis* in the general make-up of the body, the stripes, the tubercles and the spiracles (Fig. 3). It was for this reason that *Argyria sticticraspis* was so long confused with *Diatraea auricilia* ; the points of differentiation being the rim of the spiracle of *Diatraea auricilia* instead of being jet-black is grey in colour. The wall in front of the internal filaments is studded with minute papillae of different sizes gradually getting bigger towards the interior. There is no stage in larval existence when the tubercles become colourless. The fully mature larvae are comparatively bigger in size and measure from 25 to 30 mm. in length and about 4 mm. in breadth.

Larval details and chaetotaxy

Number of sclerites, setae and punctures are the same as in the larva of *Argyria sticticraspis*. The head setae A_1, A_2, and A_3 are almost in a right angle, resembling the arrangement met with in *Diatraea saccharalis*. Seta A_1 is more anteriorly removed from A_2 and puncture Aa is more approximated to A_2 than in *Argyria sticticraspis*. P_1 far behind Adf_1 while seta P_2 and puncture Pa far behind Adf_2. The distance between frontal seta F_1 and Adf_1 is less than the distance between Adf_1 and Adf_2. Pb not in a level with P_1 but posteriorly removed and approximated to L_1. The frontal punctures Fa considerably separated from each other

FIG. 3. Side and dorsal view of *Diatraea auricilia* Ddgn.

Labrum has median setae M_1, M_2 and M_3 arranged more or less in a right angle and therefore M_2 is not posterior to M_1 but at the same level. Puncture Ma lies behind M_1 and is approximated to M_1 than to M_2 as in the case of *Argyria sticticraspis*. Only two sensory papillae of epipharyngeal shield are present in the region below and in-between M_1 and M_2. Lateral seta La_3 lies at a higher level than M_3. The epipharyngeal cones Et lie between La_1 and M_2 instead of lying between La_2 and M_3 of *Argyria sticticraspis*.

Mouth-parts.—Mandibles with second tooth pointed and prominent. Cardo is reduced and extends over sub-mentum which extends a little beyond cardo and does not fuse with its fellow of the opposite side.

Thorax.—On prothoracic shield the puncture X has shifted behind Y. XY are far removed from seta Ia than in *Argyria sticticraspis*. Puncture Z midway between Ia and Ib instead of being near Ib. Va does not occur at any stage of larval life. Rest of the setae and tubercles are similar in distribution as in *Argyria sticticraspis*.

Abdomen.—Tubercles and setae resemble those of *Argyria sticticraspis* with the difference that trapezoid tubercles are big and make an angle of 90°. No central dorsal tubercles are developed. Xb makes its appearance on eighth abdominal segment and lies ventral to Xa. IIIa always keeps its individual identity and does not come in the sphere of III tubercle.

Pro-legs.—Crochets follow the same biordinal arrangement as in *Argyria sticticraspis*, but the circle is complete though the size gradually decreases towards the exterior.

EGG

Freshly laid eggs of *Diatraea auricilia* resemble the eggs of *Argyria sticticraspis* in size, shape, colour and in general arrangement.

LIFE-HISTORY

Copulation, oviposition and hatching resembles *Argyria sticticraspis*. Freshly hatched larvae measure about 1 mm. in length. The head is black and dorso-ventrally flattened. Prothoracic shield is of a dirty white colour like the rest of the body. The larvae possess only four stripes. The dorsal stripe being absent. Tubercles are grey and spines are black in colour. The larvae avoid light and take shelter on the under-surface of the leaves. The larvae are active and fragile and great devourers of green leaf tissues.

Second instar larvae.—First moult generally occurs on the third day after hatching but in some cases it occurs after five to nine days depending upon the food available. The dorsal stripe appears after the first moult. Body is semi-transparent and alimentary canal can be seen lying within. Crochets are in a semi-circle with a fewer number of spines than found in a mature caterpillar. The process of moulting resembles *Argyria sticticraspis* and each moult takes from thirty to forty-five minutes. There are five moults before the larva reaches maturity. The duration of various instars depends on the nature of food available.

The larval period varies considerably in different larvae hatched from the same egg mass. Some pupate after thirty days of larval life while others may take thirty-five to forty days and even more. It has been observed that larvae reared on shoots failed to pupate. They would always leave the shoot and pupate outside. It appears that mature larvae are incapable of making exit holes by boring through several layers of leaves. This explains why *Diatraea auricilia* does not occur in young plants and is only fond of grown-up canes. The internodes harbouring this borer fail to grow to a normal size.

Pupal period.—The pupal period lasts from eight to ten days. The progress of pupation is as follows :—

1st day.—Head region brown while body yellowish white, spiracles projected, stripes present.

2nd day.—Abdomen pale yellow, stripes persisting.

5th day.—General colour yellowish brown, eyes reddish brown and frontal horns dark brown.

8th day.—Pupa deep dark brown, no rolling movement of the posterior end.

10th day.—Emergence of the adult.

Summary of the life-cycle

Emergence of the imago completes the life-cycle. The incubation period takes five days, larva thirty-five to forty days and pupa eight to ten days, the whole cycle covering a total period of forty-five days in the laboratory during March and April.

Seasonal history

Over-wintering larvae are stimulated to activity by the beginning of February and emergence of moths takes place by the middle of February and continues up to the end of March. The eggs of the first brood were freely laid in the laboratory cages but they were not found on the aftermath or ratoon. Moths of second brood came out in laboratory cages by the beginning of April, while some larvae emerged as late as the end of April. The second brood occurred during April and May. During this period not a single plant was found harbouring *Diatraea auricilia* larva either on the sprouts of the stubble or on the plant cane. With the breaking of monsoon and sowing of paddy, *Diatraea auricilia* larvae were found infesting paddy in June and July and sugarcane in September when the rains were over. Its infestation in grown-up canes was at its maximum in October and November. It appears that there are five generations in the year. How the first two generations are passed in the field could not be ascertained in spite of a thorough search in the majority.

of the graminacious crops growing in the vicinity of Pusa. It has not been recorded so far from the western districts of the United Provinces.

Diatraea venosata (Wlk)

ADULT

The wing expanse in females is 30 to 35 mm. and in males about 25 to 30 mm. Zehntner's [1898] account of *Diatraea striatalis* Snellen of Java closely applies to that of *Diatraea venosata* Wlk. in the length of labial palpi which are as long as the head and thorax, suffused with dark in males and ochraceous in females. Antennae are similar and so is the general colouration of the wings. Apex of fore-wing is drawn out to a fine point. In males the posterior border of fore-wing is sloping. The cell area is imperceptibly formed and the black spot of scales lies at the basal angle of the cell. Marginal spots are inconspicuous in males but prominent in females. The only difference being that there is a greater wing expanse in the females of *Diatraea striatalis* which varies from 36 to 38 mm. It may be due to climatic variations. These features leave very little doubt that the two are not identical.

Head.—Front rounded and protruded in males, flat in females. Antennae flat and lamellate in males. The segments are wider than long and serration is deep. The ocelli are absent altogether. Labrum straight with pilifers well-developed. Labial palpi long and pointed.

Wing venation: Fore-wing (Plate XXXVI, Fig. 3a and b).—The fusion of Sc and R_1 is more pronounced. The two diverge just near the margin into Sc and R_1. R_2 is approximated to the stalk of R_3 and R_4 and coalesced with the latter in females. Branch R_4 bigger than the stalk while R_3 smaller. M_2 and M_3 arise together but not stalked. R_4 to A_1 the veins are equidistant at the margin.

Hind-wing.—Sc + R_1 and Rs similarly disposed as in *Diatraea auricilia*. M_1 arises from Rs just when the latter is to fuse with Sc + R_1, beyond the cell. Angle PTV less than 90°. M_2 and M_3 are stalked for a distance. The stalk being smaller than either M_2 or M_3. Cu_1 curved near the angle of the cell. Cu_1a removed from the angle while Cu_1b arises a little beyond the cell.

Female genitalia: Internal.—The various structures are disposed on a plan very much resembling those of *Argyria sticticraspis*.

External.—Single stylet supports the collar of ninth segment. Genital opening without any chitinous plate but surrounded by chitinous folds which extend within to a circular girdle from where the ductus bursae is continued to bursa copulatrix. The ductus bursae is short but has several chitinised longitudinal folds below the girdle. Bursa copulatrix is dilated and signum is absent.

Male genitalia: Internal.—Similar to *Argyria sticticraspis*.

External (Plate XXXVII, figs. 5 and 6).—Vinculum slender, rounded and flat drawn out to a fine point posteriorly. Anellus plate extending as an arm from vinculum to support the adeagus tube. Juxta membraneous and closely applied to adeagus which is tubular and bears spines; penis large and prominent provided with several rows of spines. Harpes bluntly triangular and reduced. Tegumen, gnathos and uncus chaelate.

PUPA

The fronto-clypeal is flat with two spines. A sort of roughness which neither resembles ridges of *Argyria sticticraspis* nor the spines of *Diatraea auricilia* is present on fifth, sixth and seventh abdominal segments. It is bounded by a streak posteriorly which appears white in reflected light or when viewed from behind. These streaks persist as white lines after the emergence of moths. Two short and thick spines are present in the dorsal half of the anal segment, directed upward and backward.

LARVA

The caterpillars are comparatively larger in size than other borer larvae and measure from 25 to 30 mm. in length and are about 4·5 to 5 mm. in thickness. Stripes are four, violet in colour, dorsal stripe being absent (Fig 4.). The stripes of the two sides do not run with each other on the eighth abdominal segment. The tubercles are very big and are jet black in colour. Anterior trapezoid tubercles are round while the posterior ones are oval, the two lie at an angle of 35°. Ventral tubercles are grey instead of black. The tubercles lose their colour by the middle of October when hibernation commences. At this stage the caterpillar resembles the larva of *Chilo zonellus* in the colouration of the stripes. The two can be easily recognised from each other by the grey colour of the tubercles in the larvae of *Chilo zonellus*.

FIG. 4. Side and dorsal view of *Diatraea venosata* Wlk.

Spiracles and supra-spiracular tubercles lie on the lateral stripes, the former being latero-posterior of the latter instead of being directly below the tubercles, as in *Argyria sticticraspis* or *Diatrea auricilia* larvae. The spiracles are rounded than oval and lie on tracheal vessel which can be easily seen through the transparent chitin. The rim of the spiracle is jet black with grey space inside. The disposition of the filaments and papillae resembles *Diatraea auricilia*.

Larval details and chaetotaxy

Head.—Puncture Adfa lies ahead the junction of adfrontal suture with the longitudinal ridge. Adf_2 more posteriorly removed. The distance between F_1 and Adf_1 is less than the distance between Adf_1 and Adf_2. P_2 lies beyond the level of Adf_2 as in *Diatraea auricilia* but not on the same level as in *Argyria stricticraspis*. Puncture P_a is equidistant from P_2 and P_1 and all the three lie in a line. Pa almost in a level with Adf_2. Puncture Aa and setae A_1 and A_2 in a line and equidistant from each other. A_1, A_2

and A_3 lie in an angle greater than a right angle. The puncture La approximated to seta L_1 unlike that of *Argyria sticticraspis*. Ultra-posterior setae and puncture (x) big and prominent.

Mouth-parts.—Labrum closely resembles that of *Diatraea auricilia*, the differentiation being the shuffling of the setae of the median group towards the notch. The puncture Ma lies behind M_1 and M_2 and is equidistant from both. There is another puncture Mb posterior to Ma. The epipharyngeal papillae EP are approximated together and lie one on each side of the seta M_2.

Mandibles possess six prominent teeth which are projected and conical and clearly indicate that the larvae are great devourers of cane tissues.

Labium, maxillae and mentum built on the same plan as in *Argyria sticticraspis* or *Diatraea auricilia*. Cardo is heavily chitinised and has no glove-shaped projection. Its internal outline is convex and hangs over the sub-mental sclerites. The latter arise from the region of stripes and run up to the base of cardo.

Thorax.—The number of setae and punctures on prothoracic shield similar to *Argyria sticticraspis*. Puncture X and Y behind one another as in *Diatraea auricilia*. Puncture Z nearer to seta Ib. Shield is black at border and greyish brown pigment spots are absent. A prominent mid-dorsal fissure present. Seta IXa and IXb lie on a common tubercle and IXc fuses with its fellow of the opposite side to form a bisetose ventral tubercle in front of the leg. On meso and meta-thorax IXa, IXb and IXc are present as in *Diatraea auricilia* and *Argyria sticticraspis* and Va resembles the latter. Central dorsal tubercle is single on meso-thorax but it is divided into two on meta-thorax, one on each side of the mid-dorsal line.

Abdomen.—Trapezoid tubercles make an angle greater than 90°. Central dorsal tubercles are not present. Va is not repeated on any abdominal segments. IIIa always remains separate.

Life-history

Eggs are laid as described for *Argyria sticticraspis*. Incubation period takes from five to six days, larval existence continues from twenty-one to thirty days and pupation lasts from ten to twelve days during the active season. The larvae shrink in size at the approach of pupation and the tubercles lose their colour. The larva, spins a semi-transparent silken nest before pupation and lies quiscent in the nest during the pupal change. Over-wintering larvae take about fifteen days in pupal stage. The total period taken by one life-cycle varies from six to seven weeks.

Seasonal history

It attacks sugarcane in North Bihar during the monsoon months of July, August and September when cane is actually formed. It does not occur in young shoots. Its ravages are localised. It may occur abundantly in one field while it may be altogether absent half a mile away. The borer is at its maximum activity in September. Its intensity of attack goes down in October when hibernation begins. Some of *Diatraea venosata* larvae begin to hibernate from the middle of September and emerge in the following

spring. In laboratory cages larvae hibernated from the 20th of September 1930 and emerged as moths on the 9th of March 1931. During the period they are absent from sugarcane they abound freely in *Saccharum fuscum* (Ikri) and *Saccharum spontaneum* (Batri). This borer has recently been recorded from Dehra Dun and its life and seasonal histories are being worked out.

Chilo zonellus (Swinhoe)

ADULT

Wing expanse of females varies from 25 to 30 mm. while those of males measure from 20 to 25 mm. only. The colouration of males differs from the account given by Hampson [1896] of *Chilo simplex* Butler. The costal area of fore-wing is not darkish but brown. The dark specks are more in number than what has been indicated by Hampson. It resembles *Crambus zonellus* Swinh. [1884], in its brown shadowy band running from apex of the fore-wing to the centre but differs in the colour of abdomen which is ochraceous instead of whitish. The last joint of labial palpi is never long but it is the shortest.

Head.—Front is bulging and is drawn out in the form of a conical projection. The cone is as much pronounced in males as in females. Antennae are flat and lamellate in males, filiform in females. Ocelli are present on black tubular projections just adjacent to antennae. Labial palpi three-jointed and double the length of the head. The last joint is short and conical. Maxillary palpi are ochraceous with last joint massive, flat and club-shaped. Labrum straight and pilifers present.

Wing-venation: Fore-wing (Plate XXXVI, fig. 4*a*).—Apex of the fore-wing rectangular in males but acute and produced in females. General description of veins resembles those of *Argyria sticticraspis* in both fore and hind wings. R_1 from the middle of the cell, approximated towards Sc which is free. R_2 is approximated to the stalk of $R_3 + R_4$ at its origin. The stalk is bigger than its branch R_3 but smaller in comparison to R_4. R_5 straight and from below the apex of the cell. PTV curved and the angle undifferentiated. All the veins are equidistant at the margin.

Hind-wing (Plate XXXVI, fig. 4*b*).—Sc + R_1 and Rs arise free but anastomosing in front of the cell. The fusion persists for about two-thirds the length of the wing when they diverge again into Sc + R_1 and Rs. M_1 arises from Rs within the area of the cell and, therefore, PTV originates from M_1 and makes an angle of 90°. M_2 and M_3 are stalked. Cu_1a from before but near the lower angle of the cell. The area of the cell is diminished and therefore, the apex of the cell is very much drawn in towards the base. Cross-vein PT in much reduced and TV is eight times the length of PT.

Female genitalia : Internal.—The various structures constituting the internal genitalia resemble those of *Argyria sticticraspis*.

External.—Ovipositor similar and so also the stylets attached to it. Genital opening lies in the notch on the chitinous plate on the eighth abdominal segment. Ductus bursae is lightly chitinised at its origin and bursa copula is much trix is without a signum.

Male genitalia : Internal.—Testes single, disc shaped. Vasa deferentia prominent and well separated. They in their course narrow down to swell up again into vesiculae seminalis. The two open into a triangular sinus by a

very narrow tube. The lateral extremities adjacent to the junction of vesiculae seminalis are extended below and are approximated together to form the accessory glands which lie below in convoluted loops. The apex of the sinus is drawn out into a tube—the ejaculatory duct—which opens on the adeagus.

External (Plate XXXVII, figs. 7 and 8).—Vinculum rounded and drawn out posteriorly, lateral walls thick and massive. Anellus triangular with huge lateral lobes arising from its dorsal margin. The distal extremity of the lobe resembles the fluke of an anchor, ventrally the anellus possesses a calcar with a long, stout spur projecting to a considerable distance below the adeagus and studded with hairs and spines. Juxta is closely applied to adeagus dorsally and is semi-cylindrical in shape. Adeagus is a long single tube with a rounded sack at the entry of the ejaculatory duct. Penis is sabre-shaped and extends beyond the uncus, with cornutii present at its apex. Harpes with a heavily chitinised basal lobe. Sacculus reduced and costa depressed. Transitilla absent as in others. Tegumen with lateral walls broad for a considerable distance. Uncus and gnathos form a chaela.

Pupa

In *Chilo zonellus* fronto-clypeal region is convex and bulges out towards the ventral side. Bases of wings have a semi-lunar comb-shaped prominence with a golden lustre. The pupa resembles much that of *Diatraea auricilia* in the nature of spines of fifth, sixth and seventh abdominal segments, the only point of differentiation being that in *Chilo zonellus* these spines do not extend beyond the spiracles on the seventh abdominal segments.

Larva

General

The larva (Fig. 5) measures from 20 to 25 mm. and resembles the caterpillars of *Diatraea auricilia* and of *Argyria sticticraspis* in general disposition of the body and its tubercles. But the stripes are four, dorsal stripe absent, where it resembles *Diatraea venosata* but the jet black tubercles of the latter do not occur (Fig. 5). The larvae show a sexual dimorphism in the disposition of grey tubercles and stripes, which is not hitherto marked in other striped caterpillars. In one form, the trapezoid tubercles are big and prominent and all the four tubercles lie very close to each other. In such a case the two sub-dorsal stripes are less prominent and run on the borders of these tubercles and are well separated from each other as in fig. 5(*a*). The moths developing from such larvae are generally female. In the other form the trapezoid tubercles are of medium size, less prominent and are well separated from each other. The violet stripes are very prominent and run over the tubercles. These two sub-dorsals stripes run with each other anteriorly, posteriorly and in the middle of the trapezoid tubercles on each segment as in fig. 5(*b*). The developing moths from such larvae are mostly males. Sometimes it becomes difficult to decide whether the larvae will give rise to male or female moths. In such cases greater importance in sex determination should be placed on the size of tubercles than the stripes.

Spiracles.—The jet black rim and the internal filaments guarding the stigmatal opening resemble those of *Argyria sticticraspis* but the space within is dark here.

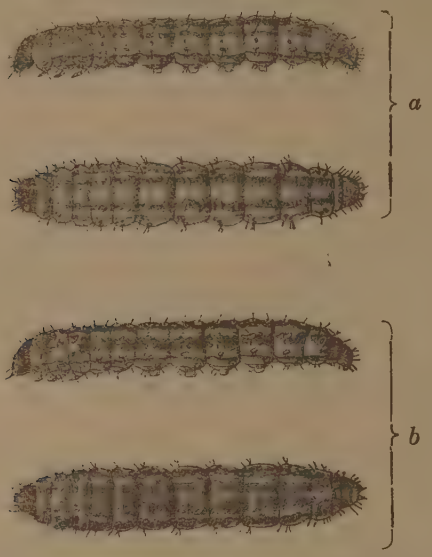

FIG. 5. Side and dorsal view of *Chilo zonellus* Swinh.

Larval details and chaetotaxy

Head.—It is light brown in colour with dark brown mouth-parts. Seta P_2 lies at a level with Adf_2 as in *Argyria sticticraspis* and unlike that of *Diatraea auricilia* and *Diatraea venosata* where it is considerably thrown back. Puncture Pa is approximated to P_2 and consequently the distance between Pa and P_1 is more than in any of the larvae described above. The distance between Adf_1 and Adf_2 is more than the distance between Adf_1 and adfrontal seta F_1. Punctures Fa well separated. Aa, A_1 and A_2 close together and in a straight line. The distance between A_3 and Aa less than the distance in any of the larvae described in the preceding pages. Ultra-posterior setae X surround the puncture posteriorly.

Labrum.—M_3 at a higher level than La_3, M_1, M_2 and M_3 possess a puncture each. The puncture Mb of M_1 lies in front of it towards the notch. Mc latero-posterior of M_3 and Ma latero-posterior of M_2 and behind M_1. Epipharyngeal sensory cones lie between the setae M_3 and La_3. Sensory papillae are absent. Cardo glove-shaped and projected. Sub-mentum sclerites extend beyond the base of cardo.

Thorax.—Pro-thoracic shield has usual number of setae. The puncture X is absent. Y near the seta Ia as observed on the prothoracic shield of *Argyria sticticraspis* and *Diatraea venosata.* Z is approached to Ib. IXa and IXb correspond with IXab of *Diatraea venosata* with the only difference that they lie on separate tubercles. On meso- and meta-thorax the tubercle Va is setaless and resembles Va of *Argyria sticticraspis* in colour and *Diatraea venosata* in size. IXa is present anterior to leg on meso- and with the addition of IXb on meta-thorax. Single puncture is present on the first joint of each thoracic leg which ends in a straight spine.

Abdomen.—Usual number of setae and tubercles are present with Va repeated prominently on first to seventh abdominal segments. It is characteristic of *Chilo zonellus* but does not occur on eighth, ninth and tenth abdominal segments. Trapezoid tubercles from second to eighth abdominal segments possess two to four deep brown pigment spots in front of the setae. These spots never occur on the anterior trapezoid tubercles of the first abdominal segment. Pre-spiracular tubercle IIIa is joined to III on the first abdominal segment in cases where the stripes are running together but it is free in others.

Pro-legs.—Crochets are arranged in a circle decreasing in size towards the exterior. The spines are arranged in triordinal series, smallest lying between the medium and biggest.

Life-history

Copulation and oviposition resemble *Argyria sticticraspis*. Hatching occurs in the early hours before sunrise. There have been cases when hatching has been noted about 10 A.M. and 4 P.M. The larvae after coming out from the egg measure from 2 to 2·5 mm. in length about 0·25 to 0·3 mm. in breadth. Head and prothorax is dark brown while the rest of the body is translucent, dirty white in colour. Tubercles are violet instead of grey or brown as has been noted in *Argyria sticticraspis* and *Diatraea auricilia*. Stripes are absent and pro-legs are peg-like with two to three crochets.

Larvae are fond of maize leaves and are attracted by light at this stage. It was observed in the laboratory that all the larvae collected on the side of the jar which was facing the window. When this lighted side of the jar was turned away from the window the larvae again collected on that side which was then facing the window. If the jar is inverted the larvae immediately take an about-turn and crawl upward. One of their peculiar habits is of collecting together. These habits explain the crowding of these larvae on the tassel of the maize plants which generally harbour as many as fifty larvae. The sexual dimorphism in the larvae is evident after the first moult.

Duration of the larval period.—In active season it lasts from sixteen to twenty-four days. They undergo the usual number of five instars covering a period from two to eleven days. It is seldom that one or two larvae prolong their larval life to as many as thirty days hatched from the same egg mass.

Pupa stage.—The various colour changes from yellow to brown are undergone in the same way as has been described in the case of *Argyria sticticraspis*. The pupal period taken by males and females differs in different months. In the case of males it varies from four to seven days, while in females the time taken is from six to nine days.

Duration of the life-cycle.—The total period from egg-laying to the emergence of adult varies from twenty-six to thirty-five days in the active season in July, vix. egg four to six days, larva sixteen to twenty-four days, pupa five to seven days.

Seasonal history

Seasonal history resembles that of *Argyria sticticraspis*. Over-wintesing larvae begin to emerge as moths by the end of March and continue to do so till the beginning of May. The borer remains active till the middle of November. Depending upon the shortest period in life-cycle it can be presumed

that it has at least five broods. The period from the 19th of November 1929 to the 25th of March 1930, was noted to be a time of absolute rest. Fletcher and Ghosh [1921] have observed its longest resting period extending from September to about July and August. This phenomenon is rare. During the period under study not a single larva took such a long time in completing one generation.

Chilo zonellus occurs in sugarcane in case the cane fields are in the neighbourhood of those of paddy or maize. In July and August 1930 sugarcane was grown in the compound of pathological laboratory. On the other side of it rice and maize were growing in the pot-culture house of the mycological section. It was the only instance when *Chilo zonellus* larvae ocurred in sugarcane. They were infesting rice and maize abundantly.

Second instar larvae were released on young sugarcane plants on the 26th of July 1931. Many of these larvae failed to penetrate the internodes but bored the mid-rib of the leaf. The growth was very slow. The larvae entering the central leaf-sheath could chew only a part and indicated ' dead heart ' on the 14th of August, i.e. after a period of nineteen days. These young larvae did not live on the hard tissues of the cane leaves and ultimately died. Mature larvae of course thrive well on sugarcane whether young or old. Side by side the larvae were released on maize plants from $1\frac{1}{2}$ ft. to $2\frac{1}{2}$ ft. high on the same date as on sugarcane and of the same instar. The result was that dead heart was indicated on the 31st July in the youngest of the lot. While all these plants were brought to the ground on the 4th of August with the majority of leaves dead. The larval growth is more accelerated in maize than in sugarcane. It is probably the reason why *Chilo zonellus* larvae prefer young maize to old plants and this explains their infestation of the inflorescence when the maize plants are quite grown up. It is not a regular pest of sugarcane as had been indicated by Stebbing [1903]. He writes :—

> ' *Chilo simplex* so far does not appear to be a bad pest in the sugarcane at Seeraha ; it occurs far less frequently there than the other two borers. But if the insect thrives and multiplies greatly in maize which is grown throughout the district during rainy season it will certainly spread to the sugarcane if the two crops are grown near to one another.'

Conclusions

It would appear from the table of difference (Appendix) that the specific differences afforded by the structural details leave little doubt that the insects described above belong to four different species and can be easily recognised from each other by the nature of the front, the ocelli, the labial palpi, the wing venation, and the genitalia of adults, characteristic markings of the pupae and the nature of stripes and tubercles of the caterpillars.

The presence of ocelli, short labial palpi and the nature of the front bring *Argyria sticticraspis* much nearer to *Diatraea auricilia*, while the male internal genitalia of *Diatraea venosata* resemble those of *Argyria sticticraspis*. This opens a field for the study of generic position of *Argyria sticticraspis*. Any taxonomist of this group will find this thesis of great use in his further work. Besides, the information on anatomical details coupled with life-history

and seasonal incidence will help a good deal those who are trying to combat these pests and who meet them in their day-to-day work in the field of sugarcane entomology.

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ABBREVIATIONS

Chaetotaxy—	FR	Front.
	ADFR	Adfrontal ridge.
	LR	Longitudinal ridge
	Adfs	Adfrontal sutures
	E_1 and E_2	Setae of epistoma
	Fa	Frontal puncture
	Adf_1	Adfrontal seta
	F_1	Frontal seta
	A_1, A_2, A_3	Anterior setae
	Adfa	Adfrontal puncture
	P_1, P_2	Posterior setae
	Pb	Posterior puncture
	L_1	Lateral seta
	La	Lateral puncture
	O_1, O_2, O_3	Oceller setae
	Oa	Ocellar puncture
	So_1, So_2, So_3	Sub-ocellar setae
	G_1	Genal seta
	Ga	Genal puncture
	M_1, M_2, M_3	Median setae
	La_1, La_2, La_3	Lateral setae
	Ma	Median puncture
	Et.	Epipharyngeal setae
	Ep.	Epiphyrangeal papillae
	CDT.	Central dorsal tubercle

Appendix

TABLE OF DIFFERENCES

Stage	Structures	*Argyria sticticraspis* Hmpsn.	*Diatraea auricilia* Ddgn.	*Diatraea venosata* Wlk.	*Chilo zonellus* Swinh.
I. Adult	*Head and mouth-parts* (i) Front	Convex in ♂ rounded in ♀.	Conical in ♂ rounded in ♀.	Rounded in ♂ flat in ♀.	Conical and projected in ♂ and ♀.
	(ii) Ocelli	Present . . .	Present . . .	Absent . . .	Present but projected.
	(iii) Antennae .	Ringed black and white	Alternating grey and ochraceous.	Flat and lamellate with deep serration. Mixed with dark in ♂. Ochraceous in ♀.	Ochraceous in both ♂ and ♀.
	(iv) Labial palpi	As long as the head .	As long as the head .	As long as the head and thorax, last joint long and pointed.	Double the length of the head with last joint shortest.
	Wing venation (i) Fore-wing	Sc separate and unbranched. M_2 and M_3 arise separately.	Sc arises free but fuses with R_1. M_2 and M_3 arise separately.	Sc arises free but fuses with R_1+M_2 and M_3 arise together but not stalked.	Sc separate and unbranched. M_2 and M_3 arise closely but do not fuse with each other.
	(ii) Hind-wing .	M_1 arises from Rs before the angle of the cell. M_2 and M_3 arise in a common short stalk.	M_1 arises from Rs after the angle of the cell, M_2 and M_3 arise in a common stalk.	M_1 arises from Rs just at the place of its fusion with Sc and R_1. M_2 and M_3 arise in a long stalk.	M_1 arises from Rs within the area of the cell. M_2 and M_3 arise together in a short stalk.

TABLE OF DIFFERENCES—*contd.*

Stage	Structures	*Argyria sticticraspis* Hmpsn.	*Diatraea auricilia* Ddgn.	*Diatraea venosata* Wlk.	*Chilo zonellus* Swinh.
I. Adult—*contd.*	*Female genitalia* (i) Genital opening.	Funnel shaped with a tri-angular plate.	Genital opening circular with chitinous folds.	Genital opening with slightly chitinised folds but having heavily chitinised girdle below.	Genital opening with a chitinous plate having extended horn.
	(ii) Ductus bursae	Slender with chitinous folds.	Slender without any chitinous folds.	Ductus bursae with chitinous plates.	No chitinous folds.
	(iii) Signum .	Signum present .	No signum . .	No signum . .	No signum.
	Male genitalia (*a*) Internal (i) Vasa deffer-entia.	In pear-shaped pouches	In closely applied tubes	Like *Argyria sticticraspis*.	The thick tubes opening into a triangular sinus.
	(ii) Accessory gland.	A pair of thread-like single tubes.	Two thin and separate tubes.	Like *Argyria sticticraspis*.	Fully developed tubes convoluted and closely applied to each other.
	(*b*) External (i) Annellus .	Semi-cylindrical .	Incomplete ring with extended horns.	Plate-like . . .	With a flat base and very much extended lobes like an anchor.
	(ii) Juxta .	Bilobed . . .	Bilobed . . .	Membraneous and closely applied.	Semi-cylindrical, closely applied.

	(iii) Penis .	Curved and sword shaped.	Arrow-like . .	With spines . .	Sabre-shaped
	(iv) Socii .	Absent . . .	Present . . .	Absent . . .	Absent.
II. Pupa	(i) 5th, 6th, 7th abdominal segments.	Ridges present on the dorsal side of 5th, 6th and 7th abdominal segments. They extend up to the spiracles on 5th and 6th but the ring is complete on 7th abdominal segment.	Incomplete ring and spines extending up to the spiracles on 5th and 6th and extending beyond the spiracles on 7th abdominal segment.	Roughness on 5th, 6th, 7th abdominal segments with whitish streaks appearing as prominent white lines after emergence.	Incomplete ring of spines on 5th, 6th and 7th abdominal segments, none of them extending beyond the spiracles.
	(ii) Anal end .	4 spines at the anal end directed towards the posterior.	No spines . . .	Anal end with two short and thick spines.	Only projections without spines at the anal end.
III. Caterpillar.	(i) Number of Violet stripes.	5	5	4	4
	(ii) Tubercles .	Grey ; become colourless after July and in all hibernating caterpillars.	Remain of grey colour throughout.	Dorsal jet black, ventral grey, become colourless in all hibernating larvae.	Grey ; trapezoid tubercles in 2 sizes ; tubercles do not change colour, well-separated medium sized tubercles with dorsal stripes running with each other develop into ♂. Big tubercles with well-separated stripes develop into ♀.

TABLE OF DIFFERENCES—*concld.*

Stage	Structures	*Argyria sticticraspis* Hmpsn.	*Diatraea auricilia* Ddgn.	*Diatraea venosata* Wlk.	*Chilo zonellus* Swinh.
III. Caterpillar—*contd.*	(iii) Spiracles .	Oval, jet black rim with clear space inside; opening guarded by filaments.	Oval, grey coloured rim with clear space inside opening guarded by papillae.	Round, jet black with grey space, opening guarded by papillae.	Oval, jet black rim with dark space opening guarded by papillae and fibrillae.
	(iv) Head setae and punctures.	Anterior setae A_1, A_2, A_3 do not form a right angle. The distance between frontal seta F_1 and adfrontal seta Adf_1 is more than Adf_1 and Adf_2.	Ant. setae A_1, A_2, A_3 forming a right angle. The distance between F_1 and Adf_1 is less than the distance between Adf_1 and Adf_2.	A_1, A_2 and A_3 form an angle greater than a right angle.	A_1, A_2 and A_3 as in *Diatraea venosata*.
		Posterior seta P parallel with Adf_1 and Pa with Adfa.	P_1 far behind Adf_1 and P_2 behind Adf_2.	As in *Diatraea auricilia*	P_1 behind adf_1 but P_2 at a level with Adf_2.
	(v) Mouth-parts (1) Labrum	Lateral seta La_3 at a level with M_3.	La_3 at a higher level than M_3.	La_3 at a lower level than M_3 which is more approximated towards the notch.	As in *Diatraea venosata*.
		Sensory papillae of the epipharyngeal plate round about M_2.	Sensory papillae between M_1 and M_2.	Sensory papillae one on each side of M_2.	Sensory papillae are absent.
	(2) Sub-mentum	Sub-mentum in two pieces runs up to the limits of cardo and the sclerites fuse with each other.	Pieces extend beyond cardo and do not fuse with each other.	Pieces arise from the region of stripes and do not fuse with each other.	Pieces extend beyond the limits of cardo.

(vi) Thorax—Setae and tubercles.	Va with a short spine present on meso- and meta-thoracic segments.	Va does not occur at any stage.	Va present but devoid of seta.	Va present but setaless.
(vii) Abdomen—Setae and tubercles.	Central dorsal tubercles present.	Central dorsal tubercle absent.	No central dorsal tubercle.	No central dorsal tubercle.
	Va setaless on I to IV abdominal segments.	Va absent.	Va absent . .	Va present from 1st to 7th abdominal segments.
	III unisetose with IIIa in proximity. IIIa is separate from III on 2nd to 7th abdominal segments, but joins the III on 8th abdominal segment.	IIIa is always separate	IIIa always separate .	IIIa joins the III on 1st abdominal segment in cases where stripes are running together, otherwise separate.
	Trapezoid angle 50° .	Trapezoid angle 90° .	Trapezoid angle 35° .	Trapezoid angle 30°
(viii) Crochets .	Crochets are in the form of an incomplete circle open towards the exterior. Spines of crochets are biordinal in arrangement.	Crochets are arranged in a complete circle with spines following biordinal arrangement.	Crochets are arranged in a circle though the size of spines decreases towards the exterior. The arrangement of spines is biordinal.	Crochets in complete circle, size decreasing towards the exterior. The arrangement is triordinal.

CHILO TRYPETES BISSET (PYRALIDAE)—A NEW PEST OF SUGARCANE FROM THE PUNJAB

BY

KHAN A. RAHMAN, B.Sc. (Edin.), Ph.D. (Cantab.), F.R.E.S.

AND

D. N. TANDON, L.Ag., B.Sc. (Agri.)

Punjab Agricultural College, Lyallpur

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(With Plate XXXVIII)

Introduction

IN India sugarcane is damaged by several caterpillars of pyralid moths. M. Afzal Husain, Entomologist to Government, Punjab, Lyallpur studied the distribution of these borers in the Punjab in 1923 by examining sugarcane samples from all over the sugarcane-growing tracts of the province. A variety of *barani* (rain-fed) sugarcane grown locally at Sialkot yielded a species of caterpillars which was different from the common species of sugarcane borers. M. Afzal Husain gave this caterpillar the name of ' new pyralid borer '. Moths were bred out and submitted to the Imperial Research Institute, Pusa and British Museum, London, for identification. In spite of repeated submissions of fresh material annually, the pest remained unnamed till October 1938, when the senior author wrote to Sir Guy Marshall for its specific identification. This resulted in Mr G. A. Bisset naming it as *Chilo trypetes* sp. nov. (Pyralidae : Lepidoptera).

Distribution

Chilo trypetes Bisset has a restricted distribution in the Punjab and has so far been recorded from the tehsils of Pathankot, Batala, and Gurdaspur (Gurdaspur district), and Mukerian (Hoshiarpur district).

Food-plants

The pest is monophagous and feeds only on sugarcane. It has neither been found in other gramineous plants (cultivated or wild) in the fields, nor has it ever fed on such plants as guinae grass (*Pannicum maximum*), maize (*Zea Mays*), *sarkanda* (*Saccharum sara*) and a few wild grasses offered to it in the laboratory.

CHILO TRYPETES BISSET

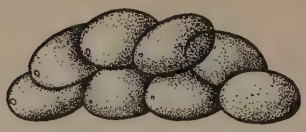

FIG. 1. Egg cluster

FIG. 2. Full-grown caterpillar (×2¼)

FIG. 3. Pupa (×2¼)

FIG. 3 *a*. Tip of abdomen of pupa (highly magnified)

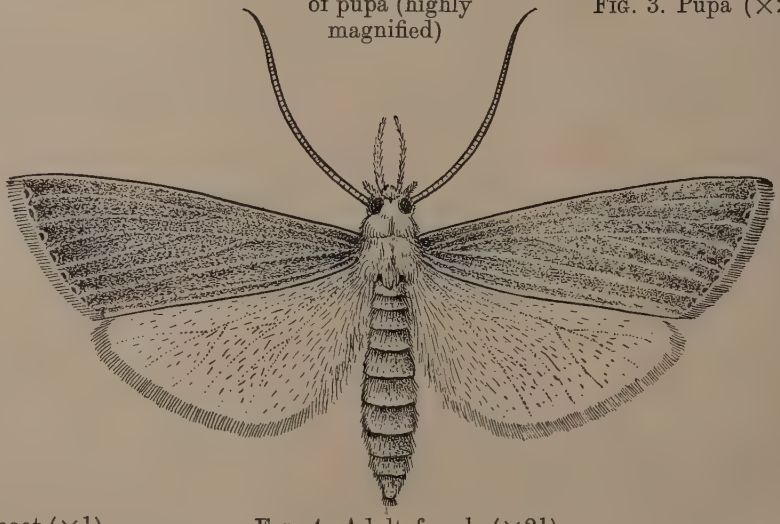

FIG. 4. Adult female (×2¼)

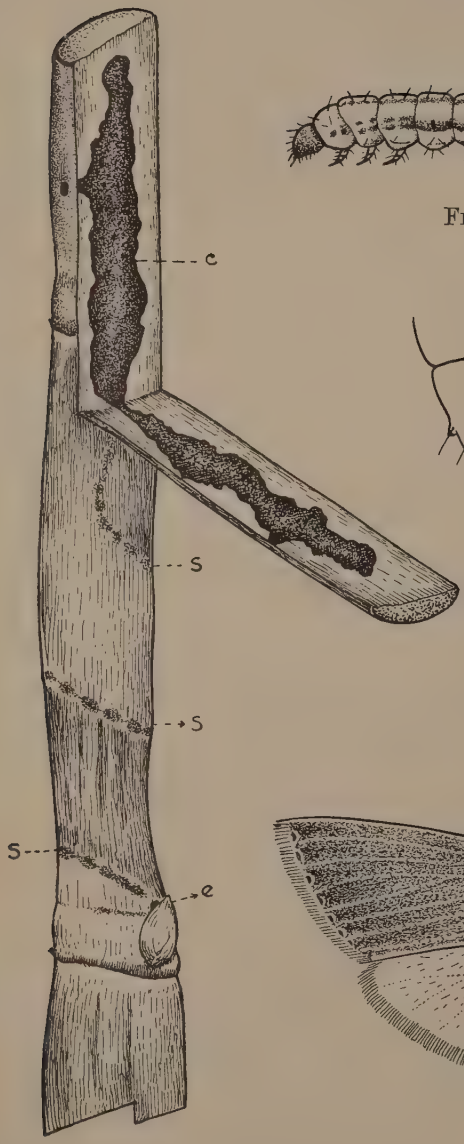

FIG. 5. Damaged cane shoot (×½)

Description of various stages

Egg (*Plate* XXXVIII, fig. 1*)

Length 0·65-0·86 mm., breadth 0·42-0·53. Flattened and scale-like. Glistening white to pale cream when freshly laid, changing to dark grey before hatching.

Caterpillar (*Plate XXXVIII, fig. 2*)

A full-grown caterpillar measures 25-28 mm. in length and 2·5-3·0 mm. in breadth. Body cylindrical, sparingly clothed in short setae which arise from tubercles. Head light orange, rest of the body creamy white ornamented with four longitudinal reddish-brown stripes situated as follows : One on each side along the spiracles and the other on either side of the dorsal vessel ; the spiracular (or lateral) stripes being very prominent, particularly between the 1st and 9th abdominal segments. Crochets on prolegs are arranged in uniordinal uniserial circle.

Pupa (*Plate XXXVIII, figs. 3 and 3a*)

Length 14-19 mm., breadth 2·3-3·0 mm. Body more or less smooth, creamy white when freshly formed, but later on changes to yellowish-brown. Thorax with a dorsal median longitudinal ridge. Abdominal spiracles oval slightly raised and deep brown in colour. Spiracular reddish-brown stripes faintly indicated. Last abdominal segment terminating in a prominent broad ridge, distal margin of which is armed with three small spines as indicated in Plate XXXVIII, fig. 3*a*.

Adult (*Plate XXXVIII, fig. 4*)

G. A. Bisset [1939] describes the moth as follows :

Male.—25-27 mm. Dorsal and lateral surfaces of the palpi, thorax, abdomen and the upper surface of the fore-wing with seven darkish spots between the veins. Under-surfaces lighter to white. Hind wings white. Labial palpi projecting forwards more than twice the length of the head ; second segment twice as long as third. Head with a conical prominence ending in a short point ; undersides of prominence flattened, the edge of the flat surface being slightly produced in front to a point directly beneath the other. Antennae serrate and finely ciliated.

Female.—29-32 mm. Similar to male but fewer dusky brown scales on the fore-wing and the antennae simple.

Life-history

The moth forces its way out of its pupal cell through the protected exit hole made for the purpose by the caterpillar before pupation. The adults become active at night when they mate, copulation lasting ten to twenty-three minutes.

* Sketches presented in Plate XXXVIII were made by M. D. Siddiqi, Artist, Entomological Section, Lyallpur, under the supervision of the senior author.

A female lays her eggs in clusters at night on the leaf-sheath near the upper nodal rings of the stem. They are arranged in rows and overlap each other like the scales on a bird's leg (Plate XXXVIII, fig. 1). Each egg-cluster contains three to sixty-five eggs.

The number of eggs laid by a female varies greatly (Table I).

TABLE I

Oviposition record of Chilo trypetes *Bisset at Gurdaspur*

Number	Pairs sleeved		Total number of eggs laid
	From	To	
1	31 July	4 Aug.	105
2	4 Aug.	8 Aug.	182
3	6 Aug.	10 Aug.	230
4	7 Aug.	12 Aug.	113
5	8 Aug.	12 Aug.	198

Thus a female is capable of laying 230 eggs in her life-time.

The eggs usually hatch in the morning. The egg-stage occupies nine to eleven days (Table II).

TABLE II

Duration (in days) of egg-stage of Chilo trypetes *Bisset at Gurdaspur*

Number	Eggs laid	Eggs hatched	Duration of egg-stage
			Days
1	4 Aug.	14 Aug.	10
2	5 Aug.	15 Aug.	10
3	9 Aug.	19 Aug.	10
4	13 Aug.	22 Aug.	9
5	16 Aug.	26 Aug.	10
6	19 Aug.	30 Aug.	11
7	20 Aug.	30 Aug.	10

The larval stage lasts for forty-eight to sixty-four days (Table III).

TABLE III

Duration (in days) of larval stage of Chilo trypetes *Bisset at Gurdaspur*

Number	Eggs hatched	Larvae pupated	Duration of larval stage
			Days
1	3 July	5 Sept.	64
2	14 July	31 Aug.	48
3	12 Aug.	5 Oct.	54
4	14 Aug.	5 Oct.	52

Prior to entering into pupation a full-grown caterpillar constructs a pupal cell in the burrow in which it was feeding. The cell is internally lined with silken threads. It also provides the cell with an exit hole by cutting out a small circular piece from the rind of sugarcane stem and covering the hole thus made by a silken web. Afterwards it transforms itself into a pupa Table IV gives the duration of the pupal stage.

TABLE IV

Duration (in days) of pupal stage of Chilo trypetes *Bisset at Gurdaspur*

Number	Larvae pupated	Adults emerged	Duration of pupal stage
			Days
1	2 Aug.	10 Aug.	8
2	4 Aug.	17 Aug.	13
3	9 Aug.	15 Aug.	6
4	3 Aug.	12 Aug.	9

SEASONAL HISTORY

The adults appear on the wing during June-July, deposit eggs and start the infestation. From July to October all stages of *Chilo trypetes* Bisset are met with in the fields, the pest completing one generation during this period. The moths of the second generation start emergence about September when they lay eggs and the caterpillars hatching out of these eggs descend to the basal portion of the cane in November where they remain till the following June.

Nature and extent of damage

Chilo trypetes Bisset starts taking toll of the crop when the plants are fairly grown up and the internodes are well formed.

The mode of entry of the caterpillars into the stem of sugarcane is quite peculiar. On hatching from the eggs they feed for a while on the buds situated on the top first or second internode and then they bore into it (internode) from near the buds (Plate XXXVIII, fig. 5*e*). They feed on the tissue first below the rind boring their way upwards (from the point of entry) in a spiral manner (Plate XXXVIII, fig. 5*s*) : externally this passage appears as a dark spiral streak, which on closer examination is found to be made up of a series of punctures (made by the caterpillars) lying side by side like the beads in a rosary. When about two-thirds of the internode is damaged in this manner, the caterpillars bore deeper into the softer tissue of the cane and feed by making a single, straight and central tunnel (Plate XXXVIII, fig. 5*c*).

Up to the second moult the caterpillars feed gregariously when there may be twenty-seven to forty-two of them in a single bore. Afterwards they disperse and lead a solitary life.

Injury by this borer is quite characteristic. In the beginning of the attack (i.e. when the caterpillars are feeding just below the rind (Plate XXXVIII, fig. 5*s*) the side leaves wither, but as the attack proceeds further (i.e. when the caterpillars have made a central bore (Plate XXXVIII, fig. 5*c*), the entire whorl of the leaves (including the central leaves) dries up and the crop presents a blasted appearance.* The attacked canes fail to grow. The dark spiral streak (Plate XXXVIII, fig. 5*s*) renders the affected internode weak, which breaks off easily when shaken by wind or a passing animal.

The damage by *Chilo trypetes* Bisset ranges from 15 to 20 per cent of the total crop during normal years, but in years of serious damage it may be as high as 50 per cent. The damage by this pest is at its maximum during August-September. *Barani* (rain-fed) crop suffers the most and, of the various Coimbatore varieties of sugarcane, Co 205 and Co 285 are the worst sufferers.

Control

Chilo trypetes Bisset is not a difficult pest to control. As mentioned above it spends the period from November to June as a resting caterpillar in sugarcane stubbles. Therefore simple, cheap and most effective method to deal with it is to plough up the sugarcane stubbles any time from November to May with a furrow turning plough. The uprooted stubbles should be collected and destroyed whenever convenient before June. A clean-up campaign in the localities where it is a serious pest will prove very helpful in subjugating it. If possible ratooning of sugarcane in infested areas should be given up.

When the attack is in progress all the damaged top shoots, recognisable by the symptoms described above, should be collected and destroyed. This is best done during July when the young caterpillars are feeding gregariously inside the top shoots.

* In case of attack by other borers it is only the central shoot that dries up and is called a ' dead-heart ', the rest of the leaves remaining quite healthy and green.

To check its inroads into uninfested localities seed cane free from *Chilo trypetes* Bisset should only be imported.

ACKNOWLEDGEMENT

This work was undertaken at the suggestion of Khan Bahadur M. Afzal Husain, Entomologist to Government, Punjab, Lyallpur (appointed Vice-Chancellor of the University of the Punjab in October 1938) to whom we are grateful both for suggesting the problem and for help and advice during the progress of this investigation.

SUMMARY

Chilo trypetes Bisset (Pyralidae : Lepidoptera) is a new pest of sugarcane which was discovered for the first time in the Punjab in 1923 by M. Afzal Husain, Entomologist to Government, Punjab, Lyallpur. It has a restricted distribution and has so far been recorded from Sialkot, Gurdaspur, Batala, Pathankot and Mukerian (Hoshiarpur). It feeds only on sugarcane and shows special preference for *barani* (rain-fed) crop.

Different stages of the pest are described and figured.

The pest is active from June-July to October when it completes its life-cycle in sixty-three to eighty-eight days. The moths of the second generation appear about September when they lay eggs and these give rise to caterpillars, which remain in sugarcane stubbles from November to June.

It begins to take toll of the crop when the plants are fairly grown up and the internodes are well-formed. Damage by this pest ranges from 15 to 20 per cent during normal years, but in years of serious attack it may be as high as 50 per cent. The leaves of the attacked cane dry up and the plant fails to grow; it breaks off easily when shaken by wind or a passing animal.

The pest can be controlled effectively by ploughing up the sugarcane stubbles any time from November to June. The uprooted stubbles should be collected and destroyed. In July the damaged canes should be removed and destroyed to kill the larvae.

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STUDIES ON EDIBLES FROM *BORASSUS FLABELLIFER* (PALMYRA-PALM) WITH SPECIAL REFERENCE TO *NIRA* OR SWEET TODDY

BY

K. MITRA, M.B., D.P.H. (CAL.), D.T.M. & H. (ENG.), F.S.S. (LOND.)

Officer-in-charge

AND

H. C. MITTRA, M.SC. (PAT.)

Chemist

Nutrition Scheme, Public Health Laboratories, Bankipur

(Received for publication on 6 March 1940)

INTRODUCTION

PALMYRA palm or *tarh*, as it is commonly known in Upper India, grows abundantly in the province of Bihar. But unfortunately this spontaneous and bountiful gift of nature has not so far been utilised to the fullest benefit of the population therein. About twenty years ago, Ghosh [1920] drew attention to this neglected source of sugar in Bihar and lamented over the fact that ' richly saccharine juices yielded by this tree are converted into toddy ' providing a cheap intoxicating drink, freely indulged in by the lower class people. On a most liberal estimate not more than 25 to 30 per cent of the trees are tapped in Bihar for this purpose.

The professional toddy tappers in this province belong to a community known as Pasis. The last census (1931) enumerated a population of 172,061 Pasis in the provinces of Bihar and Orissa of which 20,576 or 11·95 per cent were recorded to be earning their livelihood as toddy tappers and the rest were obviously their dependents.

The present investigations were started with a view to finding out how the various types of produce from palmyra-palm could be profitably utilised to the betterment of the state of nutrition of the people. This could be effected by encouraging the consumption of those edibles comparatively rich in protective elements and by better utilisation of all the possible food products from the tree. The present time seems to be a most opportune moment for dissemination of knowledge on the subject outlined above as with the introduction of prohibition in Bihar (and other parts of India as well) increasingly large number of men who had been eking out their miserable existence by tapping and vending the fermented juice (*toddy*), are finding themselves unemployed. According to Blatter [1926], who has made an extensive study on the subject of the palms of British India and Ceylon, 'every part of the palmyra-palm is turned in account in some way or other. By far the most important aspect of this tree is a source o food '.

Different edibles

Nira.—This is the Hindusthani name given to the sweet unfermented juice obtained from the inflorescence of both the male and femal trees.* There is a common belief prevalent that the sap from male trees is sweeter than that from the female. Sethi and Ghosh [1932], fter analy is of s crose content of the juice of male and female palm at Patna and Sabour, state that though individual female trees have at times been found to yield a richer juice, usually the juice from female trees is weaker in sucrose content than that of the male. The authors of this paper could not confirm their findings as this investigation was started late in the season when the juice in male trees had dried up. *Nira* is a refreshing drink with pleasant sweet taste. On keeping without preservative in hot humid climate even for a short time it gradually turns turbid and slightly sour in taste. This is how the fermentation begins.

Tarh-ka-koa.—This is the name given to the almost clear jelly-like albuminous fluid found within the shell of the young fruit. The fluid gradually hardens and assumes a white colour with increasing opacity, and develops a fibrous coat all round. During the hot months the soft gelatinous kernel (before hardening sets in) is supposed to be an exceedingly refreshing article of food. The pulp of the green fruit is sliced (minus the seed) and given to the cattle as a galactagogue in certain parts of this province.

Ripe fruit.—The mesocarp or pulp of the ripe fruit is golden coloured, luscious, sweetish and pasty in texture. Poorer people at times consume it raw or else mixed with a little amount of sugar and flour and fried n oil to make t into sweet cakes. In Ceylon the pulp is spread over mat in a thick layer, dried in the sun and preserved for consumption during winter months. This dried and preserved pulp is known there as *punatoo.*

Guthli-ka-gudda.—This is the Hindusthani name given to the cream-coloured substance of cheesy consistency which develops inside the stone of the ripe fruit as soon as small roots can be seen springing out from the fibrous surface of the seeds. It has a sweet, pleasant, taste and liked by children.

Seedlings.—When the seedlings are still very tender (about two to three months old) their beautiful parchment-like outer coating is removed and the pulp of stem is either boiled and dried in the sun or simply dried in the sun and then both of them ground into fine flour. The flour is made into various kinds of meals or gruel in South India and Ceylon.

Chemical composition of edibles

The estimation of protein, fat, carbohydrate, etc. were carried out according to the methods prescribed by the Association of the Official Agricultural Chemists [1930]. The assay of sugars was done by the well-known reducing test by Fehling's solution. The results are shown in Table I.

It is evident from Table I that with the exception of *nira* the other edibles are rich in mineral matter. They are of course not very rich sources of calcium or phosphorus. The increased concentration of calcium in treated *nira* and

* Similar sap from coconut (*Cocos nucifera*), date (*Phœnix dactylifera*) and sago (*Metroxylon sago*) palms are also known as '*nira*'.

TABLE I

Chemical composition of some of the edibles from palmyra-palm per 100 gm. of each foodstuff

Name of foodstuff	Where from obtained	Moisture per cent	Protein	Ether or fat extractives	Mineral matter	Crude fibres	Carbohydrate	Calcium	Phosphorus	Total sugar	Reducing sugar	Disaccharides	Total caloric value
			Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.			
Nira (June)	Patna	85·94	0·23	0·02	0·29	...	13·52	0·006	0·007	12·6	0·4	11·6	56·6
Nira (July)	Patna	85·89	0·31	0·02	0·31	...	13·47	0·007	0·008	12·2	0·3	11·2	56·7
Nira treated with* lime and decanted.	Patna	85·76	0·30	0·02	0·38	...	13·54	0·030	0·001	Samd as above No change in sugars			56·9
Nira treated with† lime well shaken.	Patna	86·13	0·28	0·02	0·38	...	13·19	...	...				
Tarh gur	A. I. V. I. A. Bengal	9·61	1·37	0·11	1·54	...	87·37	0·124	0·055	82·2	3·1	75·2	364·9
Tarh gur	Jaffna, Ceylon	8·32	1·04	0·19	3·15	...	87·30	0·861	0·051	82·6	1·7	76·0	364·0
Tarh gur	Experimental *gur*-making centre, Patna	8·61	1·03	0·08	1·81	...	88·47	0·225	0·044	84·0	2·0	79·9	367·7
Guthli-ka-gudda	Patna	80·99	0·75	0·12	0·85	...	17·29	0·024	0·116	...	...	...	75·1
Pulp ripe fruit	Patna	77·22	0·67	0·15	0·68	...	21·28	0·009	0·033	...	...	...	91·4
Preserved pulp	Jaffna, Ceylon	22·70	1·60	0·14	3·37	...	72·19	0·087	0·070	...	...	...	303·8
Tarh-ka-koa	Patna	92·60	0·64	0·10	0·26	0·11	6·29	0 005	0·016	...	...	...	27·0
Flour (boiled)	Jaffna, Ceylon	12·88	4·59	0·32	1·40	1·75	79·06	0·013	0·119	...	...	...	347·2
Flour (sun-dried)	Jaffna, Ceylon	12·06	4·81	0·31	1·91	1·49	80·91	0·010	0·155	...	...	...	354·2

* 0·4 gm. of slaked lime (Ca 51·45 per cent) per 200 c.c. after 10 hours. † 0·25 gm. of slaked lime (Ca 51·45 per cent) per 200 c.c. after 10 hours.

gur (jaggery) is due to the extraneous lime added as preservative. Further it appears that limed *nira* after decantation shows considerable loss of phosphorus. Probably the phosphorus of the *nira* combines with calcium in the lime and settles down as a precipitate.

The flour prepared from the seedling contains about 5 per cent protein and can compare very favourably with flour prepared from any other vegetable (particularly tubers). The food value of the preserved pulp more than justifies its introduction as an edible in areas where palmyra-palm is grown in abundance.

Carotene and ascorbic acid

The carotene and ascorbic acid content of *nira*, fresh pulp from the ripe fruit, preserved pulp, *tarh-ka-koa* and *guthli-ka-gudda* were assayed according to the methods detailed by the authors [Mitra, Mittra and Ray, 1940]. The results are given in Table II.

Table II

Estimation of carotene and ascorbic acid

Name of the edible	Carotene in mg. per 100 gm.	l-ascorbic acid in mg. per 100 gm.
Fresh pulp of the fruit	7·58	24·0
Guthli-ka-gudda	0·04	11·3
Nira	*Nil*	5·7*
Preserved pulp	12·48	12·1
Tarh-ka-koa	*Nil*	13·1

* Measured per 100 c.c.

In the case of *nira* the maximum ascorbic acid content per 100 c.c. was found to be 14·6 mg. and 8·1 mg. in a series of twenty-one estimations on different days with different samples. But the commoner findings were often in the neighbourhood of 6·0 mg. Sokhey [1939] working with coconut palm has found on average an ascorbic acid content of 8·0 mg. per 100 c.c. of fresh juice in Bombay. The fresh pulp seems to be very rich in carotene and ascorbic acid, and preserved pulp seems to be still richer in both the protective elements.

Fermentation and inversion of sugars in *nira*

Of all the types of edibles available from the palmyra-palm *nira* is by far the most abundant and at the same time extremely unstable. Sethi and Ghosh [1932], after recording the yield from twenty trees for a period of three weeks, found that the average daily yield from a tree came up to 12·68 lb.es 1·78 S. E.* Thus the daily collection of a Pasi tapping about fifteen trees

* The mean and standard error were calculated by the senior author from the table of yield supplied in the text referred to.

comes to at least 150 lb. on a very conservative estimate. This large quantity of precious juice could hardly be allowed to go to waste or converted into cheap toddy. The only alternative seems to be the preservation of the juice before its ultimate disposal.

Fermentation of the juice takes place by the action of yeasts, moulds and bacteria which split up the disaccharides (usually sucrose) at first into monosaccharides by process of inversion ('invert sugar') and finally into alcohol. The degree of fermentation undergone by any liquid for purposes of comparative study can be measured either by assessing the number of yeast cells, moulds and bacteria in a known volume on a graduated haemocytometer slide under the microscope or by estimation of alcohol. The former method was found to be tedious and trying besides being inaccurate and was consequently abandoned. The alcohol was estimated by the usual methods of distillation and corrections for temperature, etc. made according to the table compiled by Jenkins [1927].

With the beginning of fermentation this almost transparent sweet and pleasant beverage turns into an opaque and frothy juice with a slightly acid and pungent taste, commonly known as toddy. If the temperature conditions be suitable the amount of fermentation is a function of time. It was found on the average that the juice or sap with a sucrose-content of 12·4 gm. per 100 c.c. yielded 8·51 per cent proof or 4·88 per cent by volume of alcohol after thirty hours' fermentation and 11·61 per cent proof or 6·40 per cent by volume of alcohol after complete fermentation has taken place in five days' time under ordinary room temperature at Patna in the hot and humid month of July. It has been previously observed by Annett *et al.* [1916-21] in the case of date-palm juice that though fermentation or formation of alcohol may be arrested by some chemicals yet the inversion of the valuable sucrose in the juice may persist through the action of the enzyme invertase rendering the juice (or the *gur* prepared therefrom) less sweet and consequently depreciating its ultimate commercial value and attractiveness. This has been found to be true in the case of palmyra-palm juice also. *Nira* as it trickles down from the tree has an acid reaction and the *p*H was found to vary between 5·0 and 4·5. Nightly collection of *nira* in smoked pots early in the morning before sunrise gave an acid reaction and the *p*H was found in the neighbourhood of 4·5 to 4·0. Fermentation and hydrolysis of sugars in the juice completely stopped when the *p*H was 8·0 or over.

Collection of *nira*

For the purposes of this investigation the sap was daily collected in earthenware pots, '*labni*', commonly used by the tappers. The pots were fixed on to the tree for the collection of the juice every evening immediately before dusk and brought down to the laboratory for analysis at about quarter to five in the next morning. The samples were analysed and preservative added immediately on arrival. The effect of the preservative on the juice was studied after ten hours, i.e. at 3 P.M. on the assumption that within ten hours of collection the juice would be disposed of either for immediate consumption as a drink or ultimately deposited in the boiling pan for manufacture of *gur* or jaggery.

Every afternoon before sending out the pots for collection they were emptied out of their contents, washed with water, both inside and outside. The pots were then half filled with water, heated to boiling point and kept on boiling for at least fifteen minutes. The pots were subsequently emptied, heated on open Bunsen flame to kill all residual and yeast cells. Finally the pots were smoked over burning straw and leaves. It was found out by experiment (estimation of alcohol) that pots treated in such a way behaved as good as new pots as far as fermentation was concerned.

The amount of invert sugar in the juice collected in smoked pots and without any other preservatives at night was found generally in the neighbourhood of 0·5 gm. and at times exceeded 0·6 gm. per 100 c.c. in the morning. Sometimes this sugar was found to be in the neighbourhood of 0·4 gm. per 100 c.c. of the juice or even below this level.

On the assumption that the estimation of sugars in the morning collection of *nira* even in smoked pots is not likely to furnish a correct picture of the sucrose content of the juice as it trickles from the tree and basing on the authors' experience (discussed later) that lime completely stops, hydrolysis collections were made from the same tree in excessively limed and unlimed (control) pots during the night. It was found that the juice in the limed pots contained as little as 0·05 to 0·06 gm. of invert sugar per 100 c.c. which did not comprise even 0·5 per cent of the total sugar content of the juice. The juice in the control pots showed as usual ten times the amount. The spathes were thoroughly washed with clean water before the pots were tied for the night.

Preservative of choice

An attempt was made to find out a non-poisonous chemical which would not only arrest fermentation but also effectively stop inversion of sugar. Table III summarises the results of investigation with six different types of the more common preservatives tried by the authors. In each case pure E. Merck chemicals were used except in the case of slaked lime. Ordinary bazar lime with a calcium content of 51·45 per cent in finely powdered state and devoid of grits was used throughout the investigation. The formalin used being 40 per cent of solution of formaldehyde.

In each case the minimum dose of the preservative effective in arresting fermentation for ten hours had to be individually worked out by different sets of preliminary experiments. Though tapped from the same tree the samples of *nira* used were collected on different dates. The invert sugar-content of the *nira* in the experiments detailed above varied from 0·5 to 0·6 gm. per 100 c.c. and in two cases it exceeded 0·7 gm. per 100 c.c. When the invert sugar-content of the juice in the morning was found to be in the neighbourhood of 0·4 gm. per 100 c.c. proportionately a much smaller dose in each case was needed to effectively stop fermentation for ten hours. Further with a juice having an invert sugar-content of 0·5 to 0·6 gm. per 100 c.c. the fermentation could be arrested for twenty-four hours, if need be, by doses bigger than that shown in column 2 of Table III. Table IV gives the dosage of the different chemicals necessary to arrest the fermentation in both the cases.

TABLE III

Effect of chemicals on fermentation and hydrolysis of sugars in 200 c.c. of nira *in 10 hours*

Preservative used	Dose per 200 c.c. of juice	Alcohol per cent by volume (morning collection)	Alcohol per cent by volume (after 10 hours)	Total sugars, gm. per 100 c.c. (morning)	Total sugars, gm. per 100 c.c. (after 10 hours)	Invert sugar, gm. per 100 c.c. (morning)	Invert sugar, gm. per 100 c.c. (after 10 hours)	Loss of disaccharides in gm. per 100 c.c. in 10 hours	Ascorbic acid, mg. per 100 c.c. (morning)	Loss of ascorbic acid, mg. per 100 c.c. in 10 hours
Slaked lime (Ca 51·45 per cent)	0·25 gm.	0·07	0·07	11·29	11·24	0·725	0·720	*Nil*	6·31	3·21
Boric acid	0·40 „	0·03	0·03	12·28	12·20	0·420	0·640	0·19	4·89	0·52
Formalin	4 drops	0·06	0·07	12·56	12·48	0·605	1·110	0·55	6·01	1·18
Benzoic acid	0·10 gm.	0·07	0·06	12·40	12·34	0·583	1·180	0·62	6·31	1·05
Lime *plus* sodium hydrosulphite'	(0 20+0·13) gm.	0·10	0·10	12·40	12·34	0·583	1·770	1·18	4·07	?
Na-hydrosulphite	0·40 gm.	0·10	0·10	11·29	11·29	0·725	2·240	1·45	4·07	?
Salicylic acid	0·10 „	0·06	0·06	12·40	11·31	0·583	2·400	1·83	6·31	2·06

TABLE IV

Dosage of chemicals necessary to arrest fermentation in 200 c.c. of nira

Different preservatives	Minimum dose required to arrest fermentation in *nira*	
	Containing 0·4 gm. (app.) invert sugar per 100 c.c.	Containing 0·6 gm. (app.) of invert sugar per 100 c.c.
Slaked lime	0·20 gm.	0·25 gm.
Boric acid	0·30 „	0·60 „
Formalin	3 drops	6 drops
Benzoic acid	0·07 gm.	0·15 gm.
Na-hydrosulphite	0·03 „	0·05 „
Salicylic acid	0·08 „	0·17 „

It appears from the study of Table III that slaked lime, of all preservatives, tends to stop the fermentation of *nira* and also the inversion of sucrose. The effective dose 0·25 gm. per 200 c.c. comes to about 87·6 grains per gallon. Even if this quantity be exceeded it can exert no poisonous effect on the system.

When the requisite amount of slaked lime is added to *nira* and the solution is well shaken a precipitate is formed which settles down in twenty to thirty minutes leaving the supernatant liquid clear. This precipitate consists of colloidal matter and a large proportion of the phosphate and very little of nitrogen as would appear from Table I. With all the other preservatives tried the juice remained turbid all through.

Benzoic and salicylic acids according to the authors' experience were the most difficult antiseptics to tackle. Before they could exert any antiseptic action complete pulverisation was essential. Further, being insoluble in water, they could not effectively stop fermentation when placed inside the collecting pots in the evening. They could only exert their preservative properties when thoroughly shaken with the juice in wide-mouthed-glass-stoppered bottles inside the laboratory. Formalin and sodium hydrosulphite were very effective in stopping fermentation in small doses but could not prevent hydrolysis of sugars.

Lime is best put inside the pot as a thin coating and it was found essential that the same should remain moist till the trickling of the juice inside begins, otherwise part of it was converted into inert calcium carbonate. It was also invariably found that some amount of lime at the top remained undissolved

by the juice. Another difficulty was that the total volume of secretion of the nightly juice could not be definitely anticipated in the evening when the pots were tied on with the preservatives.

Provided the number of collecting pots in one tree remained constant and the temperature conditions did not undergo material alteration it was not found difficult to roughly estimate the amount of juice anticipated and consequently the dosage of lime. In the authors' series the average collection with four pots and subsequently two pots from one tree spread over a period of $2\frac{1}{2}$ months came up to 306 c.c., 415 c.c. and 517·2 c.c. respectively. The details are shown in Table V.

Approximately in a pot (*labni*) of 2-litre capacity 1·0 gm. of slaked lime was found to prevent hydrolysis and fermentation completely in a collection of about 500 c.c. during the night. Slight overdosing of the pots with lime has to be done for reasons stated above. In case the collection turns out to be too small resulting in overdosing of the juice it should be remembered that calcium compound with sucrose can be decomposed with carbon dioxide without the sweetness being impaired. But once inversion starts sucrose is irreparably lost.

The ascorbic acid is one of the most important constituents of the fresh juice from the aspect of nutrition in children. The effects of the various preservatives on this vitamin has been worked out and the results incorporated in Table III. The figures estimated after treatment with sodium hydrosulphite were misleading as this particular preservative was found to exert reducing action on the dye 2 : 6 dichlorophenolindophenol, no reliance could thus be placed on the results of titration. Another interesting observation was that ordinary slaked lime in the concentration recommended as a preservative does not completely destroy vitamin C in the *nira*.

TABLE V

Average nightly collection of the juice in c.c.

Period of collection	Number of pots tied	Average per pot in c. c.	
		Mean	S. E.
Middle of June to middle of July	4	306·0	11·96
Middle of July to 1st week of August	4	415·5	9·62
2nd to 4th week of August	2	517·2	17·07

An attempt was made to estimate the amount of levulose ordinarily present in *nira*. Of all the tests mentioned by Clarke [1934] the resorcinol test and ammonium molybdate test seemed to be of practical importance. But in the former case heating with concentrated hydrochloric acid always resulted in hydrolysis of the sucrose-content and thus the amount of free

levulose present could not be estimated. The latter test though said to be a specific for levulose could not be used for estimation in this case as it was found to yield unsatisfactory results in cases where levulose content was low.

Discussion on the findings

Except the preparation of the flour from the seedling and the preserved pulp all the edibles from the tree are consumed in some parts of this province. Now that the nutritive value of the edibles are known, people all over (wherever this tree grows wild) and the professional vendors particularly should be advised as how to utilise the produce to their best advantage both from economic as also health point of view. People may also be advised to store the ripe fruit as preserved pulp.

The main point in the problem is the ultimate disposal of *nira*. Indiscriminate propaganda on the use of *nira* as a fruit drink is likely to yield doubtful results. As in localities where one pound of *nira* costs as much as one pound of milk (this condition does exist in certain parts of Bihar) the latter should be given preference. Then again the people have to be educated into *nira*-drinking habit and arrangements made for the transport of the juice to bigger towns and cities for consumption. In rural areas very few people are rich enough to pay for such (fruit) drinks.

Recently Sokhey [1939] has suggested the preparation of levulose from *nira*, advantage being taken of the fact that in *nira*, fermentation may be stopped, but hydrolysis may be allowed to proceed by invertase so that sucrose be converted into equal parts of glucose and levulose. Levulose is a very costly sugar and may well repay the efforts but its manufacture is not possible unless a well-equipped factory arranges for the transport and regular supply of the juice and its conversion into levulose.

The other possible alternative seems to be to convert it into *gur* or jaggery according to the practice followed in Ceylon and at present in certain parts of Madras and Bengal. The details of the methods of *gur* making and its advantages are available from the reports of Gokhale [1920], Sethi and Ghosh [1932] and many others. If seriously worked out as a cottage industry *gur*-making would help in raising the economic standard of the Pasis and thereby consolidating the efforts for the success of prohibition.

Summary

All the different edibles from palmyra-palm were analysed chemically with a view to finding out their nutritive value. The most abundant produce from the tree was found to be the *nira* or the sweet sap exuding from the crushed inflorescence of both the male and female trees.

Nira, unless quickly treated with preservatives, ferments easily in ordinary temperature to form *toddy*, a cheap alcoholic drink popular with the lower classes. Of all the preservatives tried, slaked lime was found to be the most easily available, cheap and efficient in arresting fermentation as also hydrolysis of sugars. The minimum effective dosages of the other preservatives, e.g. boric acid, formalin, benzoic acid, sodium hydrosulphite and salicylic acid have also been worked out. Except slaked lime none of the others could prevent hydrolysis of sugars. The pots should be washed and smoked daily.

Nira as it trickles down from the tree contains about 6·0 mg. ascorbic acid per 100 c.c. The sugar-content is about 12 per cent. It contains no carotene.

The pulp of the ripe fruit as also the preserved pulp (*punatoo* in Sinhalese) are rich sources of vitamins A and C. The flour made out of the seedling (two or three months old) compares favourably with other common flours made out of root vegetables (tubers). *Gur* prepared from limed *nira* obtained from Jaffna (Ceylon), Bengal and Bihar have also been analysed and found to be rich in mineral matter, specially calcium.

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A RAPID METHOD OF MEASUREMENT OF LEAF AREAS OF PLANTS

BY

N. C. THIRUMALACHARY, B.Sc. (Ag.)

Cotton Breeding Station, Coimbatore

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(With three text-figures)

DETERMINATION of leaf areas of plants is one of the subjects that received the earliest and somewhat insistent attention at the hands of plant physiologists, as a result of which considerable degree of refinement and accuracy has become possible ; but many of the methods have been rendered difficult of application for developmental studies in field plants. The methods of Kidd, West and Briggs [1920] and of Watson [1937] necessitate the removal of leaves from the plant body and are not quite suitable for growth observations. Those of Frears [1935], Withrow [1935], Mitchell [1936] and Kraemer [1937] require the use of costly photo-electric apparatus and are ill-suited to field-scale operations. Gregory [1921], on the other hand, studied the correlations of a number of linear and angular measurements of the leaves of *Cucumus sativus* and formulated certain empirical relationships between them and the actual area. He found it necessary to use different formulæ for leaves of different ages which greatly reduced their direct application to field plants. A quick and reliable method satisfying this last requirement is still to be sought ; and this note embodies the results of efforts made in that direction in the course of studies on the water requirements of Cambodia cotton.

Methods and material

The material for the various measurements was derived from a field of Cambodia cotton (*G. hirsutum* L.) plants grown during 1934-35. The crop, at the time of sampling, was about four months old. The followng criteria were tested by actual measurements with a view to finding out how far each constitutes a reliable measure of leaf areas of cotton.

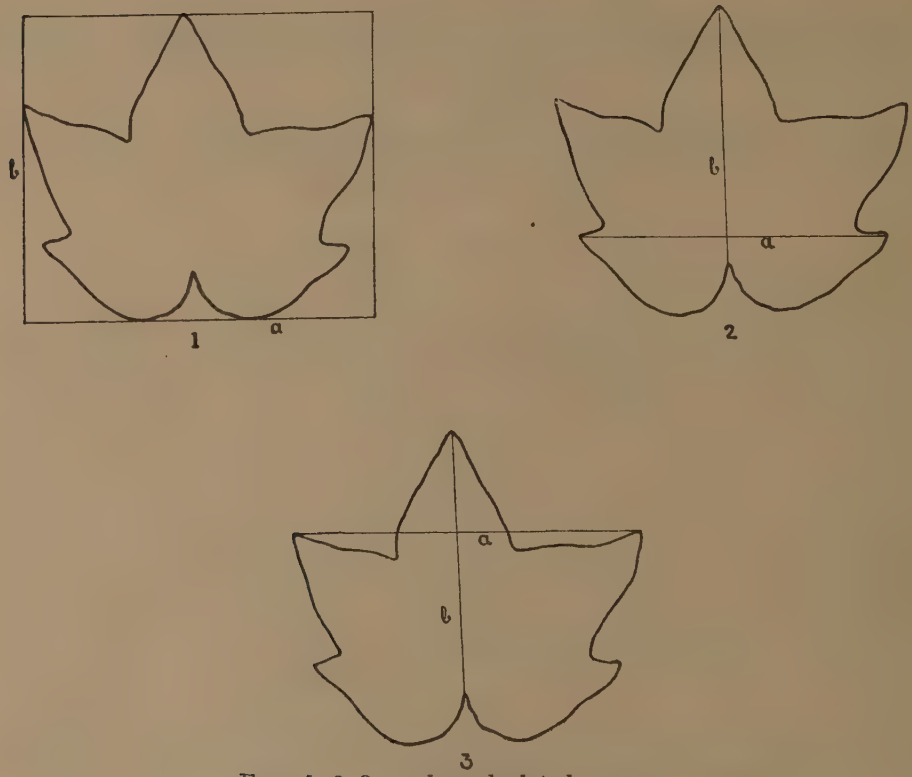
1. The area of the rectangle enclosing the entire leaf (Fig. 1).

2. The area of the rectangle the sides of which are formed by the length of the mid-rib and the maximum breadth between the basal lobes (Fig. 2).

3. The area of the rectangle whose sides can be represented by the length of the mid-rib and the breadth between the tips of the second and fourth lobes (Fig. 3).

4. By actually matching each leaf, the area of which is to be measured, against artificially prepared standards of known area cut out of ordinary cardboards.

The first three are self explanatory and do not require to be described. The last one is detailed briefly as under.



FIGS. 1, 2, 3. a × b = calculated area

About 100 leaves of ages ranging from ten to sixty days were collected from the field of Cambodia plants and their individual outlines sketched carefully on a piece of cardboard. The area of each of the 100 sketches was then carefully measured twice by means of a planimeter, and the average of the two readings was noted on each sketch. Thirty of these sketches were carefully chosen so as to constitute an ascending scale of areas. It was found that the smallest sketch was 3 sq. cm. in area and the largest was about 200 sq. cm., the difference between any two successive sketches in the scale being about 6 to 7 sq. cm. The selected sketches were cut out carefully and used as standards for matching.

The leaf, the area of which is to be measured, is then matched against its probable compeer among the standards, and the area of the closest match is taken to be the area of the leaf. It may be pointed out at this stage that a satisfactorily close match, deviating from the leaf by not more than 2 to 3 sq. cm. was almost always obtained, and greater divergences were of very rare occurrence. With a little experience the excess or deficit over the standard was easily estimated by mere eye judgment. All the final figures for the areas recorded in this note represent only such estimates.

Results

In Table I are given the results of measurements of forty-five leaves by methods 1, 2 and 3, while in Table II are given the areas of 100 leaves as measured by the cardboard method (4). In each case the corresponding areas as measured by the planimeter are also given for comparison.

Before discussing the results it may be pointed out that the first three methods do not give actual areas themselves but give only relative values of each area measured. The last method, on the other hand, gives what can be regarded as random estimates of the areas measured.

All the measurements have been statistically analysed and the correlation and regression coefficients obtained between the planimeter values and those worked out by methods 1, 2 and 3 are given in Table III. It will be seen that in all cases the correlation is high and significant. The percentage error of the regression varies from 4·9 to 3·7 for methods 1 and 2 which is not greater than that obtained by Gregory [1921]. In method 3, however, the error is considerably higher. It would, therefore, appear that for Cambodia leaves and leaves of similar shape, the complicated angular measurements used by Gregory can be dispensed with.

Further values by regression equation (Table I) were calculated for methods 1-3 and the standard deviations of the deviations of the estimates from the actual planimeter readings were worked out. For method 4 calculations were made separately for leaves below 50 sq. cm., between 50 and 100 sq. cm. and above 100 sq. cm. in area with a view to examine more closely the percentage error involved as the area of the leaf increases. The results are tabulated in Table IV.

Table I

Actual and calculated areas of cotton leaves (30 to 60 days old) in sq. cm.

Actual area as measured by planimeter	Area calculated by different methods			Area derived from regression equation		
	Method 1	Method 2	Method 3	Method 1	Method 2	Method 3
40·8	56·9	54·8	38·5	42·9	43·7	54·9
42·9	63·2	62·4	52·1	46·3	49·0	61·3
45·2	65·5	64·8	60·7	47·5	50·6	65·4
55·6	100·0	84·5	82·7	57·8	64·2	75·7
59·5	90·6	89·9	68·7	60·8	67·9	69·1
70·7	112·0	87·7	95·5	72·2	66·4	81·7
73·9	112·2	101·0	90·0	72·2	75·6	79·1
75·3	130·0	106·1	109·1	78·7	79·1	88·1
84·9	127·5	98·9	106·6	80·3	74·1	86·9
88·1	139·9	122·9	110·3	86·9	90·7	88·7
88·9	130·0	119·8	115·5	85·7	88·5	91·1
91·3	150·1	129·3	106·0	92·3	95·1	86·6
93·3	154·8	123·8	119·8	94·8	91·3	93·1

TABLE I—*contd.*

Actual area as measured by planimeter	Area calculated by different methods			Area derived from regression equation		
	Method 1	Method 2	Method 3	Method 1	Method 2	Method 3
94·0	158·7	126·7	100·9	96·9	93·3	84·3
97·5	157·4	126·4	136·3	96·2	93·1	100·9
97·6	154·9	129·9	131·0	94·9	95·5	98·4
97·7	161·6	109·4	139·2	98·4	93·4	102·2
99·6	169·7	129·2	143·9	102·8	95·0	104·5
100·3	165·1	142·7	139·2	100·3	104·3	102·3
101·7	170·6	127·0	137·0	103·2	97·5	101·2
102·5	182·3	144·0	159·3	109·4	105·2	111·7
103·2	163·8	135·3	141·9	99·6	99.2	103·5
104·8	182·1	147·4	161·5	103·1	107·6	112·7
112·8	184·9	139·6	158·9	110·8	106·2	111·5
115·5	190·3	159·7	150·0	113·6	116·1	107·3
117·2	192·7	154·4	155·6	114·9	112·4	110·0
117·8	180·9	169·7	158·7	113·6	123·0	111·4
117·9	186·0	163·2	146·5	111·3	118·5	105·7
118·1	217·1	182·1	190·0	120·8	121·5	126·1
118·3	208·8	193·4	161·2	124·4	129·3	112·6
120·0	200·2	175·5	182·1	118·9	127·0	122·4
120·4	206·7	167·9	176·0	122·3	121·7	119·5
120·8	205·8	179·1	174·2	121·3	129·5	118·7
121·3	178·2	154·1	146·1	117·2	112·2	105·5
121·8	226·2	160·3	184·9	122·6	116·5	123·7
126·3	204·3	174·0	182·4	121·0	125·9	126·6
131·4	232·1	182·4	187·2	135·7	131·7	124·8
133·5	224·0	177·6	188·4	131·5	128·4	125·4
135·9	232·4	182·7	203·3	135·9	131·9	132·4
136·6	220·3	164·7	192·6	129·5	119·5	127·4
137·7	256·7	204·5	205·7	135·8	147·0	133·5
145·2	232·5	191·0	170·2	136·0	137·7	116·8
162·6	297·2	211·7	247·0	170·3	151·9	152·8
162·8	266·1	233·6	214·7	156·8	167·1	157·7
177·4	289·6	256·7	322·1	169·2	171·0	189·2
Average 106·2	176·3	145·4	147·6			

TABLE II

Actual and calculated areas of cotton leaves (10 to 60 days old) in sq. c m. (method 4—cardboard method)

Actual area by planimeter	Calculated area	Actual area by planimeter	Calculated area
14·6	14·5	17·6	19·4
15·7	16·0	19·2	20·5

TABLE II—*contd.*

Actual area by planimeter	Calculated area	Actual area by planimeter	Calculated area
23·3	23·0	82·1	83·0
32·1	31·7	82·7	82·0
33·8	34·8	86·7	88·0
34·9	35·3	86·9	88·0
35·4	35·0	87·6	87·6
41·0	41·9	87·8	87·0
44·3	45·2	87·8	89·2
45·1	47·7	88·9	88·7
48·0	47·5	92·7	93·3
48·1	49·5	93·7	94·8
44·6	45·7	93·1	92·6
45·6	45·7	99·3	101·0
44·4	45·4	100·8	100·0
49·8	48·0	101·7	101·5
45·7	47·2	107·1	110·3
53·9	54·0	108·6	107·0
53·2	54·5	110·8	113·3
54·4	54·0	114·2	117·3
54·8	55·0	115·5	117·3
55·3	53·5	117·9	117·8
56·3	55·5	118·1	120·3
59·3	61·0	115·2	113·3
59·7	61·0	115·3	117·3
59·9	61·0	113·1	114·3
60·2	60·5	120·0	123·3
62·5	62·8	120·7	122·3
62·7	63·2	121·4	120·3
63·5	63·2	122·2	122·3
64·0	65·3	120·8	123·3
66·1	67·8	129·1	127·5
66·2	65·3	124·6	127·3
66·9	68·5	131·3	133·0
66·6	66·5	131·4	129·5
68·4	69·5	132·0	136·5
70·2	71·2	134·6	133·5
70·7	72·8	136·5	135·3
71·3	70·3	137·5	139·3
71·4	73·2	137·7	135·0
72·2	73·8	133·3	136·3
73·5	75·5	138·6	142·0
73·2	74·5	144·5	146·5
75·2	74·0	147·1	149·5
76·3	75·8	143·8	144·5
77·3	77·2	148·3	148·5
78·6	79·5	154·6	156·0
79·3	81·2	160·7	162·5
79·6	80·0	169·6	168·5
81·1	79·3	120·7	124·3
Average . .		86·85	87·44

TABLE III

Statistical analysis

Head	Methods			
	1	2	3	4
Correlation between planimeter value and those got from different methods	0·95±0·01	0·97±0·006	0·78±0·04	0·95±0·003
Regression coefficient of actual on calculated	0·53±0·026	0·69±0·026	0·47±0·056	
Percentage error of regression	4·9	3·7	11·9	

TABLE IV

Statistical analysis—contd.

Head	Methods					
	1	2	3	4		
				Below 50 sq. cm.	50 to 100 sq. cm.	Above 100 sq. cm.
Standard deviation per cent	5·6	7·0	9·3	3·25	1·61	1·37

It will be seen from the figures that standard deviation is greatest in method 3 and least in method 4; and further, in method 4 the error decreases with increase in leaf area. It is therefore clear that a greater precision in the measurement is possible by method 4. This feature and the ease with which the leaves can be handled and measured commend its adoption. It has been observed that for large-scale measurements of leaf areas, it was possible to complete, by the cardboard method, the measurements of as many as thirty-three plants with fifty leaves in each during a period of five hours which works out to more than five leaves per minute.

ACKNOWLEDGEMENTS

The author is indebted to Dr S. Kasinatha Ayyar for his valuable guidance in writing this paper. His thanks are also due to fieldman C. Sethumadhavamenon for his assistance throughout the work.

Summary

A simple method for measuring leaf areas of cotton plants, named the cardboard method, is described. This method has been found to be easier and to consume less time without any loss in accuracy. Its special advantage is the measuring of leaves *in situ* without detaching from plants and without causing the slightest injury to them such that the progressive growth as influenced by the different treatments of an experiment could be studied in one and the same plant material.

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LINKAGE RELATIONS OF THE WHITE-POLLEN FACTOR IN ASIATIC COTTONS

BY

G. K. GOVANDE

Economic Botanist to Government, Baroda

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Introduction

THE present studies were undertaken during the author's studentship period at the Institute of Plant Industry, Indore, in 1934. Preliminary work was done there but the results being inconclusive the material was carried to Baroda later in 1937. The inheritance of the white-pollen factor in a strain Cocanada 45 was shown [Ayyar and Balasubrahmanyan, 1933] to be due to a single-factor difference, the yellow colour of the pollen being dominant, and the same strain was further worked upon to find out linkage of the white-pollen factor, if any, with other factors.

Material

The strain Cocanada 45 was crossed with strains differing from it in a number of simply inherited genes with the object of discovering linkage relations of the white-pollen factor. Many strains were originally used for this purpose but only those which gave conclusive results are mentioned below with their constitution.

Strain	Constitution					
	Corolla colour	Anthocyanin pigment	Leaf shape	Lint colour	Leaf nectaries	Pollen colour
Cocanada 45	**Y**	$\mathbf{R^s}$	**l**	**k**	**ne**	**yp**
A8 Burma laciinated . .	**Y**	$\mathbf{R_s}$	$\mathbf{L^L}$	**K**	**Ne**	$\mathbf{Y_p}$
N6 multiple recessive . .	**y**	$\mathbf{r_g}$	**l**	**k**	**ne**	$\mathbf{Y_p}$

Results

The F_1 hybrids of the crosses involving both A8 and N6 with Cocanada 45 were fully dominant for the characters concerned. The summary of the results of the same grown to F_2 and F_3 generations is presented in Table I.

The data for the pollen colour and the leaf nectaries in A8 × Cocanada 45 crosses show a significant deviation from the normal 9: 3 : 3 : 1 dihybrid ratio, indicating a linkage of the coupling phase between the two factors with a cross-over value of 18·3 per cent in the F_2 and 14·7 per cent in the F_3 generations. That the whole of the discrepancy was due to linkage and not due to any disturbance in the single factor ratios was confirmed by partitioning the χ^2 for three degrees of freedom into its components in a manner shown by Fisher [1936]. χ^2 for the linkage degree of freedom alone was found to be very large and significant in each case. As regards other characters, namely leaf shape and lint colour in the same crosses and anthocyanin pigment and

petal colour as studied in N6 × Cocanada 45 crosses, with a comparatively smaller population, the deviations from the expected ratio are not significant, thus giving no evidence of linkage between any one of these characters and pollen colour.

TABLE I

Two-factor ratios in crosses of Cocanada 45 × A 8 *and Cocanada* 45 × N 6

	White pollen and	Yellow pollen		White pollen		Total	χ^2	*P*
		X	*x*	*X*	*x*			
F_2, A8 × Cocanada 45	**Ne-ne** Obs	341	47	38	87	513	164·01	V. small
	L^L-l Obs.	295	94	94	30	513	0·37	Large
	K-k Obs.	289	96	86	34	505	1·09	Large
F_3, A8 × Cocanada 45	**Ne-ne** Obs.	562	48	61	141	812	310·82	V. small
	L^L-l Obs.	314	75	101	29	519	7·29	>0·05
	K-k Obs.	270	76	77	34	457	3·66	Large
F_3, N6 × Cocanada 45	**R^s-r^g** Obs.	38	12	7	5	62	2·46	Large
	Y-y Obs.	37	14	10	1	62	2·97	Large
F_3, N6 × Cocanada 45	**R-r^g** Obs.	20	7	7	2	36	0·05	Large
	Y-y Obs.	19	8	8	1	36	1·23	Large

SUMMARY

Cocanada 45, a strain with white pollen was crossed with both A8 Burma laciniated and N6 multiple recessive in order to discover the linkage relations of the white-pollen factor in Asiatic cottons. No back-cross data are available, but other results obtained are presented here which show a clear evidence of linkage between the white pollen and leaf nectaries with cross-over values of 18·3 per cent and 14·7 per cent in the F_2 and F_3 generations respectively.

As regards other genes, namely that for petal colour, anthocyanin pigment leaf shape and lint colour the deviations from the expected ratio are not significant, indicating occurrence of free assortment, a record of equally great importance.

ACKNOWLEDGEMENTS

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A NOTE ON THE SHAPE OF BLOCKS IN FIELD EXPERIMENTS

BY

RAMJI NARAIN, D.Sc., PH.D.

AND

AZMAT SINGH

Chemical Laboratories, Agricultural Research Institute, Lyallpur

(Received for publication on 27 January 1940)

(With four text-figures)

THE success of field experiments depends not only upon the inclusion amongst treatments to be tested of all such factors upon which information is desired, but also upon the adoption of suitable forms of layout, for, as is well known, the application of even the most elaborate methods of statistical interpretation cannot overcome the disadvantages of an unsatisfactory design. There is no lack of evidence to show that soil-heterogeneity is a phenomenon of universal occurrence, and unless due consideration is paid to this factor the results of field experiments are liable to be inaccurate. There are two forms of soil-heretogeneity, viz. casual and permanent. An increase in the plot-size, maintenance of absolute uniformity in agricultural operations, correcting the surface level, etc. will remove most of the unfavourable effects of casual soil-heterogeneity. The permanent differences, irrespective of the type of crop grown, are independent of such factors, and are found to persist under all conditions. Their effects can be minimised only by adopting a suitable lay-out. In actual practice it is not uncommon to meet with both these types of fertility variations on one and the same piece of land. Examination of data from soil-uniformity trials has led a number of workers to conclude that generally speaking soil-fertility varies in particular directions. In all such cases it is a matter of considerable importance so to devise the layout that the effects of permanent differences owing to drift in soil-fertility are eliminated to as great an extent as possible. Some investigators who have devoted attention to this problem have suggested that this object can be attained by the provision of a fairly large number of replications in the trials. This, however, is not always practicable. Further, if the land acquired for providing additional replications differs considerably in fertility from that available for the original number of replications, the reduction in error aimed at by increasing the number of replications will not be proportionate. This fact has been clearly brought out by Lander, Ramji Narain and Azmat Singh [1938]. The possibility of eliminating these effects by a suitable layout of blocks and plots within blocks, however, has not received sufficient attention. It is true that the size and shape of blocks as also of plots within blocks, depend very largely upon certain practical considerations, e.g. the size and shape of the area available, the existing position of irrigation channels, roads, etc. yet even within these limitations a certain amount of choice is still available which can be exercised in a manner that is likely to increase the precision of the experiment.

A soil-uniformity trial with *chari* was conducted at Rawalpindi in *kharif* 1936. On the basis of the data obtained an attempt has been made in the present paper to present a number of alternative designs which were possible on this area and to discuss the merits of each design with a view to deciding upon the most suitable form of layout.

It is well known that the degree of precision of an experiment depends largely on the extent to which plots of as uniform a fertility as possible are included within any one block. Wishart and Sanders [1935] have discussed the merits of both square and oblong plots and, keeping practical considerations in view, have concluded that so long as areas of fairly uniform fertility can be provided for different blocks, the size and shape of the blocks and of ultimate plots become essentially a question of convenience. In other words, according to these authors, soil-uniformity within the blockexercises a far greater influence in reducing the error than the actual size or shape of plots or blocks.

In order to take away the maximum fertility differences of the land the modern field experiments require the blocks to be so laid out as to follow each other along the line of the fertility gradient. It is further emphasised that plots within any block should be as similar in fertility as possible and should lie lengthwise in the direction of greater change in soil-fertility. Further Fisher and Wishart [1930] have pointed out the necessity of having blocks as compact as possible in form. According to them long, narrow blocks are less suitable. In certain cases, however, as discussed below, greater precision is obtained, if taking into consideration the variation of soil fertility in particular directions the blocks or at least some of these are made long rather than compact.

Soil-uniformity trial data

The trial supplying the data examined in this paper was carried out on a piece of land measuring about four acres and the crop was harvested from 140 plots numbering 1, 2, 3..140, each plot being 36 ft. × 30·25 ft. or 1/40th of an acre in size and arranged in the order shown in the plan given below. The yield corresponding to each plot is also given in the plan.

	126	99	98	71	70					
127	5·7	5·6	6·5	6·2	7·2	7·4				
128	5·1	4·5	6·1	5·4	5·7	7·1				
129	4·9	4·9	5·8	4·9	5·3	6·7	43	42	15	
130	4·7	4·5	5·8	6·0	5·8	6·9	7·9	10·7	9·7	9·9	14
131	4·6	5·3	5·7	4·8	5·9	7·0	6·9	9·2	8·0	7·5	13
132	5·1	5·7	5·6	4·7	6·6	6·6	6·6	9·1	7·3	7·8	12
133	5·8	4·9	5·5	5·0	6·0	7·2	6·8	9·0	7·7	7·9	11
134	5·3	5·4	5·1	5·0	5·7	7·9	6·6	9·3	7·0	6·5	10
135	4·7	4·9	5·4	5·3	5·8	7·6	7·0	9·0	6·2	5·3	9
136	5·0	5·3	4·7	4·5	5·6	8·4	6·3	9·1	5·6	5·7	8
137	5·3	5·3	6·3	4·7	5·6	7·8	7·6	10·4	5·4	5·5	7
138	6·8	5·5	6·8	6·2	6·9	7·9	7·9	8·7	6·0	6·1	6
139	7·1	6·1	6·8	6·8	6·6	7·5	8·3	8·9	6·4	6·6	5
140	6·7	6·6	7·6	6·2	6·2	8·1	8·2	8·5	7·1	6·8	4
	113	112	85	84	57		6·5	7·3	7·6	7·0	3
							6·8	6·1	6·8	7·1	2
							6·4	6·5	6·3	6·6	1
							56	29	28		

Layout plan and yield data (maunds per 1/40th acre) of soil-uniformity crop of *chari* grown during *kharif* 1936 at the Rawalpindi Agricultural Station.

Before proceeding to discuss the data, one important point in connection with these plots, which seems to exercise a great influence on the conclusions

that may be drawn, must be mentioned. In order to supply water to the Rawalpindi Cantonment, the military authorities have constructed a number of wells from the Murree side towards the cantonment area. These wells are connected with each other by means of underground pukka channels or ducts whose level is so arranged that when the water from the last well in the cantonment area is pumped out the flow of water is automatically directed to the last well of the series. In this manner contact is maintained between the water in all the wells that go to make up the chain. A part of this water duct happens to pass beneath the piece of land on which this experiment was carried out and its direction and width is shown in Fig. 1 by two lines running parallel to each other from the north in a south-western direction. The depth of the soil lying over this duct is about 12 ft. and, as can well be imagined, this soil which had once been dug out and refilled must behave differently from the adjoining soil. About six years back, owing to the water-duct getting choked by the crumbling in of its walls, the soil above this duct was dug out and after repairing the former again put back. The fact that this soil and also that which adjoins this dug-out channel on its both sides has a different level of fertility can be seen from the soil fertility-contour map.

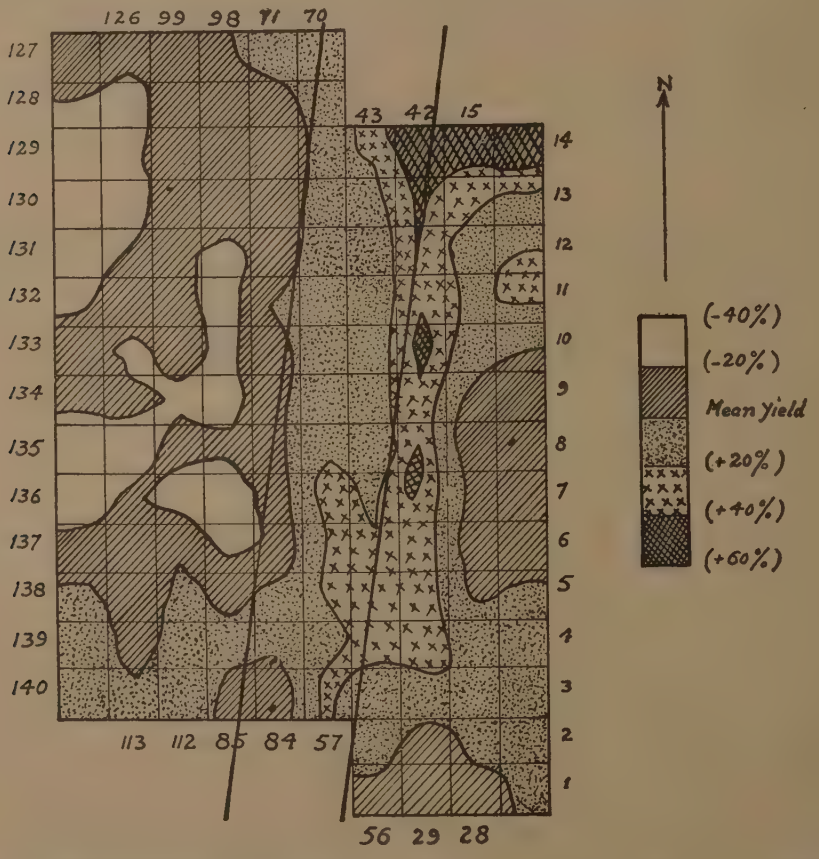


FIG. 1. Fertility contour map based on yield of *chari* (*kharif*, 1936) at Rawalpindi Agricultural Station

Discussion of results

It is clear from the contour map that soil-fertility varies much more from east to west than from north to south. This means that if the blocks are so laid out as to follow each other from east to west there is a greater possibility of the land within these blocks being more uniform than it would be if these were to follow each other from north to south. It is seen that the area affected by the water-duct which is shown in Fig. I as enclosed between two parallel lines running from north-east to south-west is characterised by a more uniform soil-fertility than the area on either side of it, particularly on the eastern side. This may be due to the fact that during the process of digging out and refilling, the soil in this area had been mixed and rendered more uniform than before. The layout of the blocks with lengths from north to south would thus seem to be more advantageous. This is further borne out when the yield data are considered after arranging them in the form of a Latin square. This can be done after excluding three rows on both the northern and southern sides of the field, leaving 100 plots to be arranged in the form of a 10 × 10 Latin square. The analysis of variance for this Latin square is given in Table I.

Table I

Analysis of variance for 10 × 10 Latin square

Source of variation	Degrees of freedom	Sum of squares	Mean square	Ratio of variances	Remarks
Rows	9	11·23	1·248 (V_1)	2·985 (V_1/V_3) 11·698 (V_2/V_1)	Significant differences between columns and rows
Columns	9	131·39	14·599 (V_2)	34·922 (V_2/V_3)	
Error	81	33·84	0·418 (V_3)	..	Column-to-column differences significantly greater than those from row-to-row
Total	99	176·46			

For $P = 0{\cdot}01$, $n_1 = 8, n_2 = 80$, F = 2·74

For $P = 0{\cdot}01$, $n_1 = 8, n_2 = 9$, F = 5·47

It is clear from the above figures that both the row-to-row and column-to-column differences are significant but the latter are significantly greater than the former, thus confirming the conclusion already drawn, viz. that in this area there is a far greater degree of variation in soil-fertility from east to west than from north to south.

Before proceeding further, it may be mentioned that two sets of experiments were intended to be laid out on this piece of land, viz. (*a*) a study of the comparative value of different types of organic manures to be applied in different amounts, and (*b*) a study of the relative value of different artificial manures

to be applied alone as well as in conjunction with green manure. There were seven treatments in the trial with organic manures and with eight replications it could be laid out in the first fifty-six plots giving eight blocks of seven plots each. The trial with artificials had fourteen treatments, and was laid out in six blocks of fourteen plots each, the plots numbering 57 to 140. The blocks in both the trials were laid out with their lengths from north to south. Owing to the greater disturbance of the soil by the water-duct on the north east corner of the land an area corresponding to eight plots in two rows was left out on the north and a corresponding area added towards the south. This course was justified when it is considered that even after the above adjustment, the fertility of plots 14, 15, 42 and 43 was the highest of any and it is likely that the area towards the north of these plots might have shown as much, if not greater, fertility. It would have been still better if these fifty-six plots could have been shifted further down by one or two rows. The differences in the fertility of the plots affected by the water-duct had been anticipated as a result of previous experience and the actual yield data obtained from this fertility trial amply confirm the anticipation.

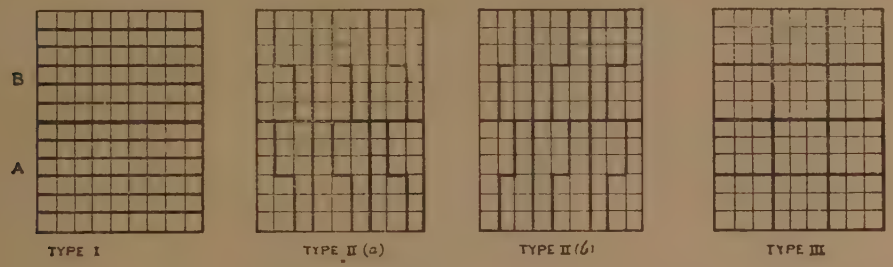
As mentioned already, although two different sets of trials were designed to be laid out on this piece of land for the purpose of the present discussion, the entire area has been considered as one piece. Further, since it is proposed to compare blocks of different shapes, it has been decided to consider only as many plots as would permit of the formation of the most compact blocks approaching as much as possible a square in shape. If thirty-two plots be excluded as follows :—

eight in the first two rows on the south,
twelve in the last two rows on the north, and
twelve in the first column on the east,

a plot combination of 9 × 12 would be left. Further dividing the area into two divisions by a horizontal line between plots 8 and 9 on the east and 134 and 135 on the west, fifty-four plots will be obtained in each division. These may be divided into six blocks of nine plots each, providing six replications of nine treatments. The six blocks in the two divisions designated as A and B can be arranged in a number of ways as shown in Fig. 2.

Arrangements represented by type I above would seem to be the simplest, but the data presented show that the relative efficiency of this arrangement is the least. Fisher and Wishart [1930] favour compact blocks as compared with long and narrow ones. In the present case the blocks could be compressed to the maximum limit if the plots within each one of them are arranged in the form of a 3 × 3 square as in type III. This undoubtedly increases the relative efficiency considerably but this increase, except for type II (*a*), is still much less than that which is possible with the other two arrangements, viz. II (*b*) and IV. This may be due to the fact that on this piece of land, the drift of soil-fertility is from east to west, while no corresponding drift is to be seen in a vertical direction. The two types of arrangements in which six plots lie in one vertical column and the remaining three are joined to these either from the lower half or the upper half of the adjoining column (type II*a* & II*b*), while making the plots compact to a certain extent, nevertheless retain the original levels of fertility differences and therefore the reduction in error in blocks of this shape is not very great. This would indicate that making the blocks as

compact as possible without taking into consideration the variations in soil-fertility does not in all cases result in an increase in the precision of the experiment. The arrangement represented by type IV in divisions A and B is based upon due consideration of the results of the uniformity trial and combines the advantages of both compactness as well as regularity in the drift of soil-fertility. It is thus clear that in one and the same trial all the blocks need not be necessarily of the same shape.



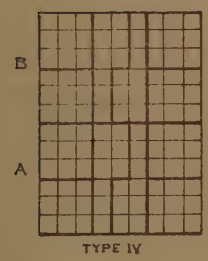


FIG. 2. Different types of arrangements (I-IV) of six blocks of nine plots each

The analyses of variance for the different types of blocks in the two divisions 'A' and 'B' are given in Table II.

TABLE II

Analysis of variance of plot yields of different types of arrangements (six blocks of nine plots each)

Type of arrangement	Source of variation	Degrees of freedom	Sum of squares	Mean square	Ratio of variances	Relative efficiency
			Division A			
I	Between blocks .	5	9·67	1·934	1·13	67·8
	Within blocks .	48	82·35	1·716		
II (*a*)	Between blocks .	5	30·89	6·178	4·85*	91·3
	Within blocks .	48	61·13	1·274		

* Significant at 1 per cent level

TABLE II—*contd.*

Type of arrangement	Source of variation	Degree of freedom	Sum of squares	Mean squares	Ratio of variances	Relative efficiency
		Division A—contd.				
II (*b*)	Between blocks .	5	45·46	9·092	9·37*	119·9
	Within blocks .	48	46·56	0·970		
III	Between blocks .	5	36·20	7·240	6·23*	100·0
	Within blocks .	48	55·82	1·163		
IV	Between blocks .	5	48·16	9·632	10·54*	127·2
	Within blocks .	48	43·86	0·914		
		Division B				
I	Between blocks .	5	1·43	0·286	0·116	37·4
	Within blocks .	48	118·27	2·464		
II (*a*)	Between blocks .	5	80·81	16·162	20·00*	113·8
	Within blocks .	48	38·89	0·870		
II (*b*)	Between blocks .	5	83·59	16·718	22·23*	122·6
	Within blocks .	48	36·11	0·752		
III	Between blocks .	5	75·46	15·092	16·37*	100·0
	Within blocks .	48	44·24	0·922		
IV	Between blocks .	5	85·03	17·006	23·55*	127·7
	Within blocks .	48	34·67	0·722		

*Significant at 1 per cent level

The above conclusion has been derived by considering the entire area as one piece of land. But, as has already been mentioned, it was proposed to lay out two different types of experiment on this land, the trials with organic manures to be confined to the first fifty-six plots and those with the artificials to the remaining eighty-four. Considering the area occupied by these plots under the two sets of trials separately, it will be interesting to see how far, by arranging the blocks in a number of ways, the above conclusions arrived at from a consideration of the entire area as a whole can be borne out with respect to each of the two pieces of land separately. The area under trial with artificials was designed to include fourteen treatments with six replications. It is possible to arrange the six blocks of fourteen plots each in a number of ways of which four types are shown in Fig. 3. The analyses of variance of the four types of arrangements are given in Table III.

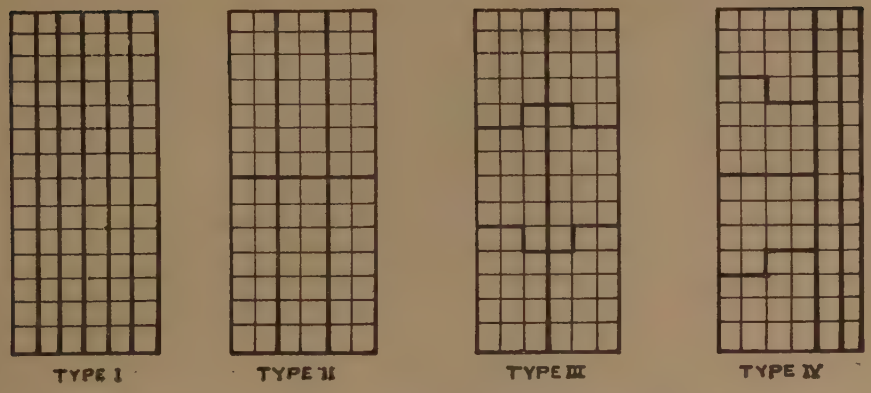


FIG. 3. Different types of arrangements (I-IV) of six blocks of 14 plots each (artificial series)

TABLE III

Analysis of variance of plot yields of different types of arrangements (six blocks of fourteen plots each)

Type of arrangement	Source of variation	Degrees of freedom	Sum of squares	Mean square	Ratio of variances	Relative efficiency
I	Between blocks	5	43·70	8·740	19·00*	155·0
	Within blocks	78	35·85	0·460		
II	Between blocks	5	32·62	6·520	10·83*	118·5
	Within blocks	78	46·93	0·602		
III	Between blocks	5	23·96	4·790	6·72*	100·0
	Within blocks	78	55·59	0·713		
IV	Between blocks	5	56·71	11·340	38·84*	244·2
	Within blocks	78	22·84	0·292		

* Significant at 1 per cent level

It will be seen that type III represents the most compact form of blocks which could be arranged on this piece of land and type I the least. In type IV the compactness has been introduced after taking into consideration the drift of soil-fertility and thus, of the six blocks, whereas four are as compact as possible, the remaining two are long and narrow ones with their lengths running parallel to the drift of soil fertility. The remaining (type II) gives some compactness but not as much as type III.

The figures for relative efficiency given in the last column (Table III) show that whereas type III is the most compact form of arrangement yet its efficiency is the least of all. Type IV has proved to be the most efficient of all the arrangements considered and as compared with the most compact form it is nearly two-and-a-half times more efficient.

Considering the area reserved for trials with organic manures the three types of arrangements considered are given in Fig. 4.

FIG. 4. Different types of arrangements (I-III) of eight blocks of seven plots each (organic series)

The analyses of variance for these three types are given in Table IV.

TABLE IV

Analysis of variance of plot yields of different types of arrangements (eight blocks of seven plots each)

Type of arrangement	Source of variation	Degrees of freedom	Sum of squares	Mean square	Ratio of variance	Relative efficiency
		Organic series				
I	Between blocks	7	38·13	5·450	4·68*	84·7
	Within blocks	48	55·90	1·165		
II	Between blocks	7	46·68	6·670	6·76*	100
	Within blocks	48	47·35	0·987		
III	Between blocks	7	63·72	9·100	14·42*	156·4
	Within blocks	48	30·31	0·631		

* Significant at 1 per cent level

Here also the conclusions arrived at from a consideration of the area reserved for trials with artificial manures are fully borne out. When all the blocks are kept long and narrow, the relative efficiency is the lowest. On the other hand when all these eight blocks are made compact the efficiency increases appreciably. The greatest increase, however, takes place when the two blocks affected by the water-duct are kept long and narrow and the remaining six made compact.

The above discussion clearly shows that to increase the precision of the experiment compactness of the blocks is of use only when it results in making the area within the blocks more uniform than it would be otherwise. If by making the blocks compact the area included within any one of these becomes more heterogeneous than otherwise, it is better not to attempt such a compression. It is no disadvantage if the shape of all the blocks included in a trial is not similar. Whatever may be the shape of the blocks, the only point to be aimed at should be that the land within the blocks is as uniform as possible.

SUMMARY

1. The results of a soil-uniformity trial with *chari* grown at the Rawalpindi Agricultural Station have been presented and considered in a number of ways.

2. Fertility contours indicating variations in soil-fertility met with on this piece of land have been drawn.

3. The drift of soil-fertility indicated by the fertility contours has been confirmed by analysing the plot yields in the form of a Latin square.

4. The suggestion that the precision of the experiment could be considerably increased if the blocks were made as compact as possible has been examined in detail and it has been shown that compactness does not always result in the increase in precision.

5. The advantage accruing from the provision of compact blocks depends upon the fact that the land within these is likely to be more uniform than that within a block which is long and narrow in shape. This, however, is not always the case. If, therefore, by making the blocks compact different levels of soil-fertility are introduced within any one of them the advantages of compactness will be considerably offset.

6. It has been shown that the greatest precision in the conduct of the trial is obtained by keeping the land within the blocks as uniform as possible irrespective of the shape of the individual blocks.

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A NOTE ON THE DESIGN AND ANALYSIS OF COMPACT EXPERIMENTS WITH THREE OR FOUR RESTRICTIONS

BY

P. V. KRISHNA IYER, M.A.

AND

SUDHIRCHANDRA SEN, M.Sc.

Imperial Agricultural Research Institute, New Delhi

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Introduction

PATERSON [1933] in dealing with the modifications of Latin square gives a type of layout, called ' magic square', in which every treatment occurs once in each row, once in each column and once in each quarter. ' The statistical methods ', he says, ' are the same as those described for the randomised block or Latin square layout. The sums of squares due to similar groups of plots, e.g. blocks, rows, columns, sections, treatments, etc., are subtracted from the total sum of squares for all plots, leaving a residual sum of squares and the residual number of degrees of freedom on which the measure of significance depends '. The method given by Paterson for the analysis of compact experiments involving more than two restrictions is too brief and is not clear regarding the orthogonal aspects of the various items involved in the analysis of variance of such experiments. This note illustrates the method of analysis for such layouts.

Material

A manurial experiment, consisting of twelve treatments, each replicated six times and laid out in a compact block in such a way as to effect elimination for soil-heterogeneity in three different ways, has been utilised for the purpose of illustration. The experiment was conducted in *kharif* 1939, and maize was grown to see the manurial effect.

The plan of the layout together with the yield of corn and the three restrictions imposed on the same layout are given below :—

C 18·51	K 25·46	A 21·60	B 23·91	E 25·46	F 26·23	D 22·63	G 20·57	L 21·60	J 15·43	I 18·77	H 18·26
F 19·03	L 25·71	I 25·20	D 26·74	J 30·08	K 19·80	B 22·63	H 23·14	G 22·63	A 18·00	E 14·91	C 18·77
E 16·46	H 21·86	J 30·86	G 24·68	C 23·91	I 22·88	L 27·26	A 17·48	F 19·28	D 17·48	B 17·74	K 16·46
B 17·36	D 25·71	K 31·75	F 22·37	H 21·08	A 24·17	J 25·71	E 24·43	C 20·31	I 21·08	L 21·86	G 14·66
G 21·86	J 24·68	L 21·60	C 23·40	D 16·46	B 18·00	K 27·90	I 19·03	H 22·88	E 15·43	A 12·60	F 20·06
I 20·57	A 15·68	E 13·88	H 17·23	L 13·63	G 19·03	C 21·08	F 14·40	K 20·06	B 11·44	J 17·74	D 18·51

Plan of the layout and yield of corn in lb.

C	K	A	B	E	F	D	G	L	J	I	H	
F	L	I	D	J	K	B	H	G	A	E	C	*a*
E	H	J	G	C	I	L	A	F	D	B	K	
B	D	K	F	H	A	J	E	C	I	L	G	
G	J	L	C	D	B	K	I	H	E	A	F	*b*
I	A	E	H	L	G	C	F	K	B	J	D	

Arrangement I

	c			d				e				
C	K	A	B	E	F	D	G	L	J	I	H	
F	L	I	D	J	K	B	H	G	A	E	C	
E	H	J	G	C	I	L	A	F	D	B	K	
B	D	K	F	H	A	J	E	C	I	L	G	
G	J	L	C	D	B	K	I	H	E	A	F	
I	A	E	H	L	G	C	F	K	B	J	D	

Arrangement II

C	K	A	B	E	F	D	G	L	J	I	H	
F	L	I	D	J	K	B	H	G	A	E	C	
E	H	J	G	C	I	L	A	F	D	B	K	
B	D	K	F	H	A	J	E	C	I	L	G	
G	J	L	C	D	B	K	I	H	E	A	F	
I	A	E	H	L	G	C	F	K	B	J	D	

Arrangement III

Method of analysis

The sums of squares for blocks for arrangements I and II shown above are calculated separately in the usual way, each having five degrees of freedom. The sum of squares for blocks for arrangement III is not orthogonal with those for I and II. On a careful examination, it will be found that the sum of squares for arrangement III includes portions of the sums of squares which have already been included in arrangements I and II, viz. sum of squares for sections *a* and *b* and sum of squares for sections *c*, *d* and *e* respectively shown in the

above figures. Thus the actual elimination for soil-heterogeneity effected by imposing the third restriction is 337·2199 (total s. s. for III)−56·4985 (s. s. for sections *a* and *b*)−255·5508 (s. s. for sections *c*, *d* and *e*)=25·1706 with 5−(1+2) or 2 degrees of freedom. The sum of squares for treatments is calculated in the usual way.

The final table of the analysis of variance is as follows.

Analysis of variance

Variance due to	Degrees of freedom	Sum of squares	Mean square	S_1^2/S_2^2
Restriction I	5	252·5619	..	..
Restriction II	5	304·8828	..	..
Restriction III	2	25·1706	..	..
Treatments	11	227·5826	20·6893	1·873
Residual error	48	530·1893	11·0456	..
Total	71	1340·3872		

Thus the effect of treatments can be judged with greater precision in this modified layout than in the ordinary randomized block layouts.

In the example cited above, three restrictions have been imposed on the layout. Another layout with four restrictions is given below.

f	H	G	I	J	L	K	B	A	D	C	F	E	*a*
	B	A	D	C	F	E	H	G	I	J	L	K	
g	F	E	K	L	D	C	I	J	B	A	H	G	
	I	J	A	B	H	G	E	F	L	K	D	C	*b*
h	D	C	E	F	B	A	L	K	G	H	J	I	
	K	L	G	H	J	I	D	C	E	F	B	A	

Arrangement I

c				*d*				*e*			
H	G	I	J	L	K	B	A	D	C	F	E
B	A	D	C	F	E	H	G	I	J	L	K
F	E	K	L	D	C	I	J	B	A	H	G
I	J	A	B	H	G	E	F	L	K	D	C
D	C	E	F	B	A	L	K	G	H	J	I
K	L	G	H	J	I	D	C	E	F	B	A
i						*j*					

Arrangement II

H	G	I	J	L	K	B	A	D	C	F	E
B	A	D	C	F	E	H	G	I	J	L	K
F	E	K	L	D	C	I	J	B	A	H	G
I	J	A	B	H	G	E	F	L	K	D	C
D	C	E	F	B	A	L	K	G	H	J	I
K	L	G	H	J	I	D	C	E	F	B	A

Arrangement III

H	G	I	J	L	K	B	A	D	C	F	E
B	A	D	C	F	E	H	G	I	J	L	K
F	E	K	L	D	C	I	J	B	A	H	G
I	J	A	B	H	G	E	F	L	K	D	C
D	C	E	F	B	A	L	K	G	H	J	I
K	L	G	H	J	I	D	C	E	F	B	A

Arrangement IV

The analysis is done on the same lines as the one with three restrictions. The sums of squares for arrangements I, II and III are calculated in the same way as discussed in the previous example. The sum of squares for arrangement IV is equal to total sum of squares for IV—sum of squares for sections f,g, and h—sum of squares for sections i and j, the degrees of freedom being 5—(2+1) or 2. The analysis of variance table showing the degrees of freedom for the various items is given below :—

Variance due to	Degrees of freedom
Restriction I	5
Restriction II	5
Restriction III	2
Restriction IV	2
Treatments	11
Residual error	46
Total	71

Maximum number of restrictions and designs

It will be of interest to note that the maximum number of restrictions that can be imposed on a certain layout is dependent on the number of replications and the number of treatments. The following table gives the maximum number of restrictions with different numbers of replications and treatments, each block being a compact rectangular unit.

Number of treatments	Number of replications	Maximum number of restrictions
4	4	3
6, 12, 18, 24, 30, 36	6	4

The lay-out for four treatments, replicated four times with three restrictions, can be formed without much difficulty, and the plan below represents a design involving six treatments, each replicated six times, with four restrictions.

a	b	c	d	e	f
d	e	f	a	b	c
c	f	b	e	a	d
e	a	d	c	f	b
b	c	a	f	d	e
f	d	e	b	c	a

Plan showing six treatments with four restrictions

For an experiment involving six treatments, it is possible to have $\underline{|6} \times 1936$ designs with four restrictions. The method of forming any one of them is described below. For convenience, this method, which is applicable to all the cases, is discussed with special reference to the arrangement shown in the plan above. The six treatments which are represented by the letters *a*, *b*, *c*, *d*, *e* and *f* can be arranged in $\underline{|6}$ ways, and the first row can be any one of them. Taking the first row as *a b c d e f*, the second row can be arranged in 2^4 ways after taking into consideration the fact that the letters *d* and *c* should not occupy the third and fourth columns of the second row. Out of these 2^4 arrangements, let us take the one shown in the second row of the above plan, viz. *d e f a b c*. When once the first two rows are fixed, the columns 1 and 2, 3 and 4, and 5 and 6 of the third row can be filled up only by three specific pairs of letters. In the plan shown above, they are *c f*, *b e* and *a d*, and it is evident that they can be permuted in 2^3 ways. Now coming to the fourth row, the first and the second halves are *e a d* and *c f b*. Since *a* or *d* and *c* or *f* cannot occupy the first and the sixth columns respectively, *e* and *b* are fixed at those places. In the general case, two columns of the fourth row, one on each half of the row are fixed. After fixing *e* and *b*, *a* and *d* (of the fourth row) can be put in 2 ways, and one of the arrangements, viz. *a d* is taken here. The letters coming below *e* and *b* in the two remaining rows can be taken in 4 ways, and in this particular case, we have taken *b f* and *e a*. The letters at the second and third columns of the fifth and sixth rows, viz. *c a* and *d e* can be filled up easily at this stage, and the remaining six letters, viz. *c f*, *f d* and *b c* get automatically fixed satisfying the required conditions.

The design for the layout involving twelve treatments can be had from the same layout by replacing each of the letters *a*, *b*, *c*, *d*, *e* and *f* by a_1, a_2;

b_1, b_2 ; c_1, c_2 ; d_1, d_2 ; e_1, e_2 and f_1, f_2 respectively, $a_1, a_2 \ldots\ldots\ldots f_1, f_2$ being the twelve treatments. It may be mentioned that the treatments within each of the six groups (i.e., a_1, a_2 ; b_1, b_2 ; $\ldots\ldots\ldots f_1, f_2$) should be randomized separately.

The layouts for the other experiments involving eighteen, twenty-four, thirty, thirty-six, etc. treatments can be formed on the lines indicated above by dividing them into groups of three, four, five, six, etc. treatments respectively.

Summary

The paper deals with the design and the method of statistical analysis of compact experiments with three and four restrictions. It is not recommended that experimenters should adopt such designs in general, but in cases where an increased precision is expected by such a layout, the correct analysis should be as indicated in this paper.

REFERENCE

Paterson, D. D. (1933). *Trop. Agric.* **10**, 303-17

NOTES

NOTICE NO. F. 1-9 (5)/40-A, DATED THE 19 JULY 1940 ISSUED BY THE GOVERNMENT OF INDIA, IN THE DEPARTMENT OF EDUCATION HEALTH AND LANDS

IT is notified for general information that an Order similar to the Importation of Plants (Amendment) Order of 1940, dated April 10, 1940, issued by the Ministry of Agriculture and Fisheries, London, which was published with this Department notification No. F. 1-9 (3)/40-A., dated the 29th May, 1940, has been issued by the Secretary of State for Scotland and came into operation on the 1st May, 1940.

NOTICE 2 OF 1940—APRIL TO JUNE 1940

THE following plant quarantine regulations and import restrictions have been received in the Imperial Council of Agriculture Research. Those interested are advised to apply to the Secretary, Imperial Council of Agricultural Research, New Delhi, for loan.

I. List of United States Department of Agriculture, Bureau of Entomology and Plant Quarantine Services and Regulatory Announcements

1. *Quarantine and other official announcements* :—
   (*i*) Mexican Fruitfly Quarantine—modification of regulations.
   (*ii*) Pink Bollworm Quarantine—modification of regulations.
2. *Summaries of plant quarantine import restrictions* :—
   (*i*) Union of South Africa—restrictions on the importation of potatoes.
   (*ii*) United Kingdom of Great Britain—revision of the digest.
   (*iii*) Republic of Cuba—White-fringed beetle—importation of certain products prohibited from infested areas.
   (*iv*) Republic of Mexico—Amendment to Exterior Quarantine No. 12. Abrogated—Alfalfa seed from Muma country, Arizona.
   (*v*) Kingdom of Egypt—importation of certain fruits and plants prohibited.
3. *Service and Regulatory Announcements.*—Index, 1938.

II. Other Regulations.

1. *Iraq.*—Importation of Plants Law No. 31 for 1938.
2. *Colony and Protectorate of Kenya* :—
   (*i*) Plant Protection Ordinance, 1937—Rules,
   (*ii*) Government Notices Nos. 969 & 970,
   (*iii*) Amendment of Schedules.

PRIZE FOR A DESIGN OF AN IMPROVED AGRICULTURAL IMPLEMENT OR MACHINE

IN order to encourage inventors to improve existing implements of cultivation and to design new implements and machines better suited to Punjab conditions and within the power of the average cultivator to purchase, the Punjab Government has instituted a scheme of prizes for a suitable design of a particular improved agricultural implement or machine. These prizes are open to all (including Government servants) irrespective of nationality.

Last year a prize of Rs. 3,000 was offered for a simple and cheap Winnower to separate *bhusa* from grain after the wheat crop has been trampled out by bullocks. None of the entries received in competition was considered to be free from defects, but for the most promising entry, in the opinion of the Judging Committee, Government awarded a sum of Rs. 1,000 to Messrs. H. T. Satterford, Superintendent of Workshops, Punjab College of Engineering and Technology, Moghalpura, Lahore, and Lekh Singh, Overseer, Punjab Agricultural Engineering Section, Lyallpur, for their design of pedaldriven machine. This design is now being improved and in due course it is intended to arrange for the manufacture of the machine on a mass-production basis.

This year another prize of Rs. 3,000 has been advertised for a suitable design of a cheap, bullock-drawn, automatic, multiple-row sowing drill, entries for which should reach the Director of Agriculture, Punjab, by the 30 September 1940 at latest.

REVIEW

The breeding of herbage plants in Scandinavia and Finland. (*Joint Publication No. 3 of the Imperial Agricultural Bureaux.*) Pp. 124. Price 4*s*.

ARRANGEMENTS have been made between the various Imperial Agricultural Bureaux whereby any publication upon the preparation of which two or more Bureaux collaborate shall be included in a new series entitled Joint Publications. It has been decided to regard the earlier Joint Publications on '*Vernalization and phasic development of plants*' and '*Erosion and soil conservation*', as Nos. 1 and 2 in this series. Other Joint Publications produced in recent years but already out of print have not been given numbers in the series.

The Imperial Bureau of Plant Breeding and Genetics and the Imperial Bureau of Pastures and Forage Crops have now produced Joint Publication No. 3, entitled '*The breeding of herbage plants in Scandinavia and Finland*'. It is a symposium consisting of a series of articles by acknowledged specialists in the respective countries. G. Nilsson-Leissner, F. Nilsson, E. Akerberg and R. Torssell contribute articles on work in Sweden, H. N. Frandsen, H. Wexelsen and O. Pohjakallio on Denmark, Norway and Finland respectively.

Each article reviews recent developments in the countries concerned, including details of the most recent improved strains of grasses, clovers and lucerne, and the methods used in producing them, as well as a contribution on the application of cytology to herbage plant breeding. The articles vary from 5 to 35 pages in length and are mostly quite detailed, each being provided with a mass of tabular data and selected bibliographies. The Scandinavian countries are recognized authorities on grassland and breeding problems and the bulletin provides an invaluable outline of achievements up to date. This is made specially clear by a useful summary of the entrie contents of the bulletin which appears at the beginning, before the presentation of the individual articles. Another useful feature is the provision of a list of addresses of the research stations concerned and of maps illustrating their locality.

The bulletin covers 124 pages and is obtainable from either Bureau at the moderate price of 4*s*. Standing orders for Joint Publications should be placed with the Secretary, Imperial Agricultural Bureaux, 2 Queen Anne's Gate Buildings, London, S. W. 1. Wherever any Empire country orders bulk supplies direct from the Bureau in one order (i.e. 50 copies or more) a discount of 25 per cent will be allowed.

GIPD—132 ICofAR—12-10-40—750.